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National innovation systems and global innovation networks

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Executive summary

Innovation is a complex phenomenon that involves many players, their collaborative networks, and their ability to take advantage of inter and intra network knowledge flows, as well as the various national and local institutional arrangements within which the players relate. The main focus of this project report is on key factors that can facilitate the transformation of GPNs into GINs within the national context. It will do this by exploring the national innovation systems (NIS) of six European countries, Germany, the United Kingdom, Denmark, Norway, Sweden and Estonia, plus four of the largest and fastest growing emerging countries: China, Brazil, India and South Africa. These four countries designated the CIBS countries, have the potential to become southern engines of global economic growth, but they can appear to pose a threat as they become increasingly more competitive with Europe. Nevertheless, the main driving force behind the emergence of global innovation networks is the centrality given to cooperative relationships and collaborative learning and technical change.

One of Adam Smith's great insights was that *cooperative* production increases productivity. This confirms Freeman’s (1991) observation that production networks are as old as industrialized economies, and given that innovation often occurs within these networks, innovation networks are not a new phenomenon. One phenomenon that has increased in importance in recent years has been the rise of *collaborative* innovation, which involves a coordinated effort between enterprises and other organizations to solve a problem, such as developing a new product, process or form of organization. Similarly, the globalization of production began will before Adam Smith, but it too has gained in importance in recent years as national economies are becoming increasingly integrated through trade, foreign direct investment, capital flows, migration, and the spread of technology. The outcome has been that already existing *global cooperative production networks* are evolving into *global collaborative innovation networks*.

Collaborative innovation networks are essential for the creation, transfer and absorption of new knowledge and ultimately economic growth. Collaboration is important because it reduces the risk and complexity involved in the development of new products and processes by spreading it among several partners with agreed complementary aims. It often entails the development and acquisition of new capabilities, as each agreement involves a shared commitment of resources and knowledge, and encourages interactive learning. Collaborative agreements between firms and other organizations also represents the formalized links or global networks in which individual firms operate, and may include agreements within an enterprise group, up-stream suppliers, downstream customers, competitors, the government and universities and other research institutes. These agreements can be formal and ridged, usually encompassing a collaborative agreement or strategic alliance with long-term

objectives, or they can be informal, flexible and trust-based relations, often linking enterprises with various local actors. The form of ownership, the location of a partner within the network, and the strength of ties between partners can have important consequences.

Global collaborative innovation networks make it possible to transcend national boarders, but they do not replace the institutional arrangements that support the national innovation system. Some global networks are planned on a large scale, usually by large multinational enterprises; with production, marketing and R&D activities coordinated from one central location, but carried out in locations throughout the world. Other global networks evolve in a self-organizing way; containing individual collaborative agreements that facilitate cooperation through technology cross-licensing, outsourcing, joint ventures and R&D agreements, and other types of innovative activities. The institutional arrangements of the national innovation system set the rules of the game for each location, or node, within the innovation network. Innovation networks often form because enterprises need certain kinds of technical knowledge they are unable to generate themselves, but they also reflect existing relationships and network capabilities.

A basic premise of this report is that *national* innovation system remains important for the development of *global* innovation networks. The national innovation systems approach to economic performance considers the flow of knowledge and technology among people, enterprises and institutions. It is primarily a systemic methodology that Chris Freeman defined as “the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.” These institutional arrangements “govern the transfer of various types of knowledge, such as intellectual property, know-how, software code or databases, between independent parties.” The OECD points to evidence suggesting that the “most innovative firms are those with the ability to access outside knowledge and to link into knowledge networks, including informal contacts, user-supplier relations and technical co-operation,” but they also emphasize that these firms “also need the ability to adapt the technology and knowledge to their own needs.” Over the past decade the creation, use and diffusion of new knowledge has increasingly become more of a collective endeavour, shaped by a combination of institutional arrangements and knowledge-sharing systems.

Bengt-Åke Lundvall developed an interactive learning perspective to innovation systems, which considers the interrelationships between actors involved in the creation and use of technical knowledge to be central to the innovation process. Recurrent interactions generate dynamic capabilities and the kind of knowledge necessary for creating new products and processes. Continuous interactive innovation necessarily involves non-market relationships of a network type. While there are many different kinds of networks in our lives, Chris Freeman was the first to use the term “networks of innovators” to describe the kinds of networks that are most relevant to the innovation system. Innovation networks represent knowledge flows both within and between enterprises and organizations, irrespective of national borders, but they are also part of the institutional arrangements underlying the innovation system. They can be formal, usually expressed as a collaborative agreement or strategic alliance, or they can be informal or of a tacit nature, often linking enterprises with various local actors. The main reason for being part of an innovation network is that it enables enterprises to recognize “opportunities for linking flexible specialisation across the boundaries of firms, and for triggering continuous interactive innovation.” Innovation networks are generally organized with a core enterprise, usually a multinational enterprise, with both weak and strong connections between constituent members, which may or not be a wholly owned affiliate.

Networks of innovators make it possible to transcend national boarders, but they do not replace the institutional arrangements that support the national innovation system. An important finding of this study is that two different types of global innovation networks coexist within each country. One type centres on large multinational corporations, which consider their market to be global and attempt to coordinate production, marketing and R&D activities from one central location. The second type involves many different actors, some tied together through ownership, and others through an agreement or alliance, which evolves in a self-organizing way. Cooperative relationships within the innovation network can take on different forms. These relationships include joint ventures and R&D agreements, technology licensing and exchange agreements, knowledge seeking foreign direct investment, outsourcing, research associations and knowledge banks, government and inter-governmental joint research programmes, and other networks, including various informal networks. The national innovation system becomes important in that it sets the rules of the game for each node within the innovation network, and for the actors entering into a relationship.

The organization of the study is out outlined as follows. Chapter one discusses some concepts and issues related to national innovation systems, global production systems and the emergence of global innovation networks. The second chapter explores the possibility that global production networks are transforming into global innovation networks from a comparative point of view. This chapter finds that knowledge sharing and collaborative learning are rather prevalent within the European countries included in the study and between Europe and the United States. The CIBS countries have much less access to these networks, but there are signs in all of the countries, especially China and India, that their global production network is gradually including knowledge transfer agreements indicative of an innovation network.

Two of the largest Member States of the European Union are covered in chapters three and four. Germany is the largest Member State, with a large and diversified science and knowledge-based economy, and appears as a coordinated market economy with certain liberal features that encourage the development of private sector innovation. By contrast, the United Kingdom is generally viewed to be a liberal market economy more similar to the United States. The UK has a strong science base and strong innovation capacity in the services sector, but with a relatively low R&D spending relative to GDP in the enterprise sector.

Chapters five, six and seven cover three small Scandinavian countries. All three Scandinavian economies are small, open and dynamic with similar institutional arrangements, but the economic structure each of these economies appears quite different. Denmark has a large number of entrepreneurially based small and medium-sized enterprises; Sweden relies heavily on large knowledge based enterprises; and Norway is a resource-based economy that relies heavily on knowledge based services. All three countries rely heavily on collaborative learning, often jointly with each other, to remain on the technology frontier.

Estonia appears as an interesting case of a catching-up economy in the analysis and is covered in chapter 8. It is a relatively small Member State with relatively low productivity levels, but high productivity growth. It is also has many cultural and linguistic ties to the Nordic countries, and as the report shows, also quite well integrated into Nordic collaborative networks. Having immediate neighbours on the technology frontier with considerable foreign direct investment forced Estonia to be more global in the way it developed its capabilities and accessed markets.

The four CIBS countries are covered in chapters 9 through 12. They show both similarities and differences in their interactions with the EU. There are similarities in that all four countries are relatively large in geographic size and population, the income and wage levels in these countries are significantly behind the European average, income distribution is very unequal, and all four countries are important regional players. But they also have distinct political systems, with varying degrees of direct and indirect state involvement in the economy. All four countries are far from the technology frontier, but there are examples where these countries have become global players in certain industries, such as ICT manufacturing in China, ICT services in India and biofuels in Brazil. China and South Africa appear different because of their scepticism toward foreign ownership as a means toward accessing better technology, whereas Brazil and India more heavily rely on multinational activity and embodied technology transfer.

Despite sharing many common features, the individual CIBS countries are fairly heterogeneous, posing quite different challenges and calling for specific policy responses on the side of their partners, especially the EU. The Chinese economy is driven mainly by exports of labour-intensive manufacturing exports and domestic investment in fixed capital. India is a highly diverse economy, ranging from simple handicraft to modern production techniques, and has become a major supplier of labour-intensive manufacturing exports and knowledge intensive services. Brazil is essentially a domestic-oriented service-driven economy, but it has become a major supplier of natural resource-based manufacturers in recent years. South Africa is a bit smaller than the other three, also focuses on agro-based and resource-intensive manufacturers. The resource orientation of Norway appears to resemble the economic structures of the latter two economies, but the technological capabilities are very different.

Many enterprises located in the CIBS countries are part of a global production network (GPN), often producing various components for high technology product in a vertical value chain that require relatively low skills. Yet, there is evidence that some enterprises in these countries are actively involved in global innovation networks (GINs), which coincides with the general rise in competencies observed in these countries. But there is some network misalignment taking place. Both India and South Africa are experiencing critical skills shortages with the education infrastructure unable to provide the needed skills. In Brazil a private sector education is developing to meet that need. China has the necessary infrastructure, but struggles to develop a local innovation capacity beyond imitation and market seeking activities.

The European Union as a whole appears to actively participate in a multitude of global innovation networks and that the relatively higher productivity levels enjoyed in the United States may be misleading. Both the United States and Europe are in many of the same networks and interact on many different levels. And all of the countries contain large centrally controlled multinational enterprises that attempt to direct and control the innovation network that they are part of. They also contain smaller enterprises and research groups that interact in global innovation networks that are more self-organizing and moving with the needs of the members that are part of it. This dual nature of innovation networks fits well with the stories told in the subsequent chapters on the United Kingdom, Germany and the Scandinavian countries about different layers within each national innovation system.

This report examines outcomes from a comparative point of view and has little to offer in terms of policy prescriptions. The obvious recommendation it could make is to support policies that seek to improve networking among the actors and institutions in the national innovation system and to enhance the innovative capacity of firms, particularly their ability to identify and absorb technologies. What this report provides is a comparative analysis of the countries that are discussed in more detail in the subsequent chapters. And it tells a story about how the individual innovation systems are tied together through an evolving global network of innovators.

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Chapter 1: Introduction: national innovation systems and global innovation networks

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1.1 Introduction

Innovation is a complex phenomenon that involves many players, their collaborative networks, and their ability to take advantage of inter and intra network knowledge flows, as well as the various national and local institutional arrangements within which the players relate. Enterprises often partner to share costs, find complementary expertise, and gain access to different technologies and knowledge. Joining an innovation network also facilitates the learning process within firms by providing a way for them to observe how other firms perform and better access to specific project-based knowledge. The rise of the ICT industries and other emerging technologies, such as biotechnology and nanotechnology, has made the creation, use and diffusion of new knowledge a more of a collective endeavour. This trend toward more collaborative behaviour was shaped and mediated by a combination of national innovation systems and knowledge-sharing systems. These new networks of innovators made it possible to transcend national boarders, but they did not replace the institutional arrangements that support the national innovation system. This chapter will examine the importance of national innovation systems in the context of globalizing innovation networks.

One of Adam Smith's great insights was that *cooperative* production increases productivity. This confirms Freeman's (1991) observation that production networks are as old as industrialized economies, and given that innovation often occurs within these networks, innovation networks are not a new phenomenon. One phenomenon that has increased in importance in recent years has been the rise of *collaborative* innovation, which involves a coordinated effort between enterprises and other organizations to solve a problem, such as developing a new product, process or form of organization. Similarly, the globalization of production began will before Adam Smith, but it too has gained in importance in recent years as national economies are becoming increasingly integrated through trade, foreign direct investment, capital flows, migration, and the spread of technology. The outcome has been that already existing *global cooperative production networks* are evolving into *global collaborative innovation networks*.

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This chapter is outlined as follows. The following section provides some background analysis on why growth rates differ between the countries included in this report by examining the role that social and technological capabilities might play in closing the productivity gap. The third section presents the national innovation system perspective, focusing on the centrality of the institutional arrangements of an economy and the process of interactive learning. Section 4 describes how the production process relates to the institutional arrangements of an economy through the social systems of production. Adam Smith’s idea of the division of labour and specialization is the main topic of section 5, which is then used to explain why global production and global innovation networks exist. Section 6 goes to the heart of the issue and discusses some of the many different types of innovation networks and different varieties of collaborative arrangements. The importance of the global technology transfer network for closing the productivity gap is discussed in section 7. Many consider foreign ownership to be central to the rise of global innovation networks, and section 8 summarizes some of the important issues related to global innovation networks. Strategic alliances and strategic partnerships are central to global innovation networks, which is discussed in section 9. Section 10 provides a basic outline of the report.

1.2 Technology gaps and knowledge flows

Gerschenkron (1962) developed the idea that technological differences explain differences in growth rates and hence the possibility of catching-up and convergence. The size of the gap creates an opportunity for catching-up with the technology leader, but this opportunity will depend on whether a country below the technology frontier can successfully imitate the technological leader. Abramovitz (1986) developed this argument further by arguing that the realization of this opportunity for closing the technology gap depends not only on the relative lack of technical knowledge, but also what he described as the *social capabilities* of a country. Abramovitz and David (1996: 50) define social capability as the “attributes, qualities, and characteristics of people and economic organization that originate in social and political institutions' that influence economic behaviour." Countries below the technological frontier therefore "have the potentiality for generating growth more rapid than that of more advanced countries, provided their social capabilities are sufficiently developed to permit successful exploitation of technologies already employed by the technological leaders". The realization of this potential in countries such as China, India, Brazil and South Africa, depends on both the presence of social capabilities and the size of the technology gap.

Abramovitz (1986) sees the possibility of catching-up as the outcome of the existing technology gap, social capability and access to global knowledge networks. From this perspective, factors of technology transfer should be considered as partly independent of those governing potentiality itself, and partly as a reflection of the *social capabilities of a nation*. This would involve developing the social capability to absorb and effectively use technical knowledge obtained through global networks. This is in sharp contrast to the growth literature where the issue of how technology transfer contributes to growth is of no concern. The very mechanics of growth, or how technological, social and other independent factors interact and contribute to catching-up processes, are not of prime concern. However, from a technology transfer perspective it is the mechanics (or process) that are the main concern. The approach, which tries to take into account the interaction of these factors, is the national systems of innovation approach (Freeman, 1987; Lundvall, 1992; Nelson, 1993; and Edquist, 1997).

Technical change and technological learning happen inside the enterprise. The accumulated knowledge of the firm is sometimes referred to as the absorptive capacity to assimilate technical knowledge. Cohen and Levinthal (1989: 569) define the absorptive capacity as the 'firm's ability to identify, assimilate and exploit knowledge from the environment.' When a firm wants to apply knowledge transferred from abroad, they must enter into a time-consuming and costly process of investing in their absorptive capacity if they want to imitate or improve. The absorptive capacity of firms is related to prior knowledge, is path-dependent (non-linear) with respect to past innovative performance, and depends very much on bounded rationality of the learner (Winter, 2003). Nevertheless, the idea of absorptive capacity becomes a connecting device between the potential for catching up (technological opportunities) and its realization (appropriability conditions). This later factor is a necessary condition for firms to have incentives to invest in learning.

The idea of absorptive capacity is very closely related to the idea of technological capabilities pioneered by Penrose (1959) and Richardson (1960, 1972), with the former developing the idea of intra-firm differentiation to explain endogenous growth processes within individual firms and the latter stressing the idea of inter-firm specialization as a basis for organizing economic activities. It can also be seen in the context of Marshallian externalities that involve knowledge (technological capabilities) as opposed to economy-wide or systemic externalities (social capability). Tunzelmann and Wang (2003) are careful to point out that 'capabilities' refer to the ability of an enterprise to carry out specific tasks, whereas a firm's 'competences' represent the stock of accumulated knowledge, though the two are complementary and interdependent. Teece, Pisano, and Shuen (1997) incorporated many of these ideas into their concept of dynamic capabilities, which represents 'the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments'. This involves organizational processes (including routines), positions (relative to the value chain), and paths (patterns of change). Dynamic interactive capabilities, as Tunzelmann (2009) terms it, depends partly on the "degree to which the resources and/or products are appropriate to the changing segments and environments in which they are positioned." Winter (2003) also adds that the process of acquiring capabilities is non-linear and depends very much on bounded rationality of the learner.

Developing the capability to absorb new technologies was essential in every case of catching-up this century. Empirical studies show that few countries develop the social capabilities to close the technology gap. While the developed OECD countries have been converging over time, Baumol (1986) shows that this group of countries have also tended to grow faster than the world economy as a whole. Barro and Sala-i-Martin (1995) argue that the only convergence that occurs is so-called conditional convergence, by which they mean convergence after controlling for differences in steady states or situations in which a limited set of growth-related variables grow at a constant rate. The further an economy is 'below' its steady state, the faster it should grow and vice versa; the further an economy is 'above' its steady state, the slower the economy should grow (Jones, 1998). This suggests that the economic growth is a much more complex country-specific process, not easily amenable to generalizations.

Innovation will take place in the emerging market economies mainly by learning the use and improvement of technologies that already exist in the relatively more advanced industrial economies, and not by pushing the knowledge frontier further. Lall (2000) observed that this process involves building the capability to master, acclimatize, and improve on the acquired knowledge and equipment. Viotti (2002) emphasized that this also involves building an active learning system that supports enterprises to learn how to produce, and introduce continuous and incremental product and process innovations. This means developing the "ability of firms to integrate, build, and reconfigure internal and external competencies" as Tunzelmann and Wang (2003) put it. This means that the emerging economies should make use of the many different methods of technology transfer and the different varieties of global innovation networks. One great challenge to conceptualizing the relationship between global innovation networks and national innovation systems is the diversity of transfer channels and the different forms in which technology appears.

1.3 National innovation systems

Friedrich List (1841) recognized the importance of national institutions in building capabilities and competences. For List (1841), these capabilities and competences represent the accumulated knowledge of a nation and "is productive only in the proportion" to the nations ability "to appropriate those attainments of former generations and to increase them by its own acquirements." This idea became part of the 'national system of innovation' perspective pioneered by Freeman (1987), Lundvall (1985, 1988, 1992) and Nelson (1988, 1993). Godin (2007) identifies two general perspectives, one based on Nelson (1993), which describes the ways that nations organize their innovation systems, and the other on Lundvall (1992), which focuses on knowledge and the processes of learning. Edquist (1997: 14) provides a more general definition that includes, "all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations." While there is no single definition of a national innovation system, it draws heavily upon historical, evolutionary and institutional perspectives. In the context of global innovation networks, the original definition of national innovation system provided by

Freeman (1987) may prove best, “the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.”

The idea of national innovation systems Nelson and Rosenberg (1983, 4) single out the institutional arrangements “whose interactions determine the innovative performance of national firms.” These institutional arrangements, as Nelson and Sampat (2001) contend, are standardized social technologies, or routines, that are essential for the development of new physical technologies. In this sense they provide procedures that facilitate the creation, use and diffusion of new technologies. But when the social technologies are not suited to the new physical technologies, they become “humanly devised constraints that structure human interaction” as North (1990) maintained. The institutional arrangements can be either formal such as laws and constitutions or informal such as social norms and conventions and define the behaviour of individuals and organizations, such as firms and the government. They can also include transnational and international laws and regulations, but they will be enforced and carried out within the national context. In the national innovation systems perspective, institutions represent the source of economy-wide or systemic externalities (Chesnais, 1996) and they also define the rules of the game, within which economic actors structure and organize their relationships. Nelson and Sampat (2001) maintain that economic growth depends on the co-evolution of physical and social technologies.

Lundvall (1992) considers the national innovation system to contain “elements and relationships, which interact in the production diffusion and use of new and economically useful knowledge . . . either located within or rooted inside the borders of a nation state.” He then argues that the definition should not only include individuals and organizations directly involved in searching and exploring for new knowledge, but also the institutional arrangements and organizations that affect all forms of learning. Because knowledge is different from information and learning is different from technical change, these authors suggest focusing attention on the processes by which different kinds of knowledge are created and used in the process of innovation, or what they call the ‘learning economy’. Lundvall and Johnson (1994) identify four different types of knowledge: (1) knowing how, (the ability to do something); (2) knowing what (knowledge about facts); (3) knowing why (knowledge about principle and laws); and (4) knowing who (knowledge about who knows what). This idea of knowledge fits very closely to Polanyi’s (1958) distinction between tacit and codified knowledge and Nelson’s (1991) distinction between generic and specific knowledge. It also has roots going back to the Arrow’s (1962) idea of ‘learning by doing’ and Rosenberg’s (1982) concept of ‘learning by using’. Viotti (2002) anticipated many of these ideas when he argued that catching-up economies must have an ‘active national learning system’ if they are to absorb already existing knowledge about production.

By broadening the definition of national innovation systems perspective, Lundvall (1995; 1988; 1992) develops an interactive learning perspective to innovation systems, which considers the interrelationship between the creation and use of technical knowledge to be central to the innovation process. Recurrent interactions generate dynamic capabilities and the kind of knowledge necessary for creating new products and processes. Continuous interactive innovation necessarily involves non-market relationships of a network type, as suggested by Miettinen (2002). There are many different kinds of networks, but Freeman (1991) coins the term “networks of innovators” to describe networks that are most relevant to the innovation system. These networks represent knowledge flows both within and between enterprises and organizations, irrespective of national borders, but they are also part of the institutional arrangements underlying the innovation system.

1.4 Social systems of production

Hollingsworth and Boyer (1997) develop the idea of the 'social systems of production' to describe how the production process relates to the institutional arrangements of an economy. This idea is reminiscent of the one suggested by Nelson and Sampat (2001) that physical and social technologies co-evolve. It is rooted in the classical theorists, Adam Smith (1776), David Ricardo (1821), Wassily Leontief (1936) and Pierro Sraffa (1960), who describe the economy from a circular flow perspective, in which various inputs are transformed into outputs through the production process (Metcalfe, 2010). They focus on the technical structure of production, and the conditions required for its reproduction and expansion, without incorporating a choice theoretic into the theory that limits the behaviour of individual economic agents and organisations. Löwe (1965; 1976) provided some important insights into how the technology as envisioned by the classical economists could be seen as part of a social system of production. By considering the technology as part of, yet different from the social system of production, Löwe (1965) provided a way to explain how complex interpersonal relationships and social patterns of behaviour create the diversity of institutions and organizations. If the socialization process is removed from the technological core of economic activity, then only production relationships involving commodities are included. This approach provides a clear distinction between structure and behaviour, which makes it possible to differentiate between production systems in general from social systems of production in particular (Nell, 1984).

From Löwe's (1965; 1976) perspective, the many different varieties of capitalism appear as the range of economic means available for attaining a particular goal, such as a higher standard of living. His analysis centres on determining the optimal path of economic growth or what is sometimes called the traverse, the incentives and behaviours necessary for keeping the economy on this path, and the institutional arrangements necessary for stimulating suitable motivations and behaviours. There may be many possible paths of economic growth that could be described as desirable, each one having its own advantages and weaknesses and specific type of organization and institutional arrangement (Boyer and Hollingsworth, 1997). The institutional arrangements should have strong interlocking complementarities for the social systems of production to function effectively (Soskice, 1999). This suggests that the range of feasible paths is constrained by both technical and social systems of production. So while countries can follow different paths of economic growth toward the same goal, the constellation of complementary institutional configurations may be limited. Kim and Tunzelmann (1998) and Tunzelmann (2004) bring up a similar issue when they argue that knowledge accumulation does not depend on a particular institutional configuration, but on the interlocking complementarities within the institutional arrangements of the economy, or what they call network alignment.

The approach suggested by Löwe (1965) reverses traditional growth theory by starting from the existing technical and social structures of production, and then designs public policies that would establish an economic environment in which behaviours and motivations are consistent with the desired growth path. From this perspective, the social structure of production determines the diversity of motivations and behaviours present in both within and between varieties of capitalism. Technical change and technological learning can also be important for the growth path, as well as the policies that shape the path of institutional change.

Recognition that the social system of production is different from, yet complementary to the technical structure of production fits well with Granovetter's (1985) idea that economic relations between individuals or firms are embedded in social networks. Like Löwe (1965), Granovetter (1985) maintained that the assumption of rational, self-interested behaviour in neoclassical economic theory limits what can be said about the social relations between people in general and the nature of innovation networks in particular. Both individuals and enterprises are embedded in a network of social relations, which improves the ability of organizations to enhance interactive learning through relational mechanisms, formal contracts, and informal knowledge acquisition. Innovation networks exist only in the context where the actors are embedded in the innovation system itself and sensitive to the institutional arrangements, including the norms and values, in the society.

1.5 Production, technology and fragmentation

The classical economists were more concerned with the system of production, and the conditions for its reproduction and expansion, than of the different possibilities for producing a particular good or service (Kurz and Salvadori, 1995; Metcalf, 2010). This production system is self-reproducing, and through its systemic nature, depends on an elaborate division of labour not only within particular processes but also between them. Adam Smith (1776) explained why an ever more sophisticated division of labour was the main source of productivity growth. It increased productivity through the increase of dexterity of workers, saving time lost in switching between different tasks, and the introduction of new machines and organization that facilitated work. And it encouraged the advance of differentiated knowledge, and therefore of distinctive capabilities, which are 'knowledge how' rather than 'knowledge that', as Loasby (1988) argued. The division of labour creates both the incentive to innovate and to accumulation more capital, generating a kind of virtuous cycle. Trade theory becomes essential to the argument because the division of labour is limited by the size of the market. International trade increases the size of the potential market and provides a vent for any surplus product, but more importantly, it tends to create specialization across countries as task are subdivided into well-defined activities and products. One important implication of Smith's theory of productivity growth when combined with trade theory is that increasing fragmentation of knowledge can occur across countries and across firms, even with different forms of ownership.

Because Smith's theory of international trade was based on the concept of the division of labour it provides an essential building block for a theory of globalization. Globalization occurs as productivity growth and market growth generates international trade as knowledge becomes fragmented across different firm, organizations and national borders. International trade widens the market and gives vent to the resources that, in the absence of trade, would remain unemployed or underemployed. By overcoming the narrowness of the domestic market, international trade ensures that the division of labour is carried more fully and productivity growth is higher. A country produces products for which it is best suited (i.e., for which its absolute costs are lower) in terms of natural or acquired advantages and exchanges its surplus produce with the produce of other countries for which there is a demand in the home market. Free trade not only ensures gains to the consumers who get a product at a lower price but it also ensures more productive deployment of domestic capital.

Allyn Young (1928) developed the idea that the division of labour is a form of industrial fragmentation more fully than Adam Smith. Writing in the later half of the eighteenth century when industrial capitalism was in its infancy, Smith could not fully visualize that industrial stratification implies a division of labour across firms and industries. The idea of industrial fragmentation in Young was linked to the 1920s debate on the representative firm central to the theory of Alfred Marshall (1920). For Young, fragmentation was a response to changes in the market external to the firm. As a consequence industries would gradually lose their identity in response to changes in the external field. Neither the concept of a firm or industry losing its identity, nor that of external economies is present in Smith. But he did recognize that different specialized arts and crafts have to join hands even for the production of the most ordinary goods and services.

Adam Smith (1776, 145) certainly did not see collaboration between competitors as being good, as conversations between competitors “ends in a conspiracy against the public, or in some contrivance to raise prices.” Yet, greater specialization in enterprises entails greater inter-dependencies between enterprises, including outsourcing and collaboration (Nooteboom, 2007). This latter idea was picked up by Jones (2000) and Jones and Kierzkowski (2001) picked up on this idea and argued how increased specialization would lead to fragmentation and intra-product trade and how this process could lead to an offshoring of certain tasks to lower-wage countries. In other words, fragmentation encourages the formation of global production networks that can be both within and between firms, which then encourages interactive learning through the network. Since offshoring suggests that the ownership has become more diversified, and that networks take on the important role of providing governance in the global production system (Gereffi, et al, 2005).

1.6 Technological collaboration and innovation networks

Technological collaboration is a natural extension of Adam Smith’s ideas of the division of labour. Cook (2004) uses the term ‘collaborative manufacturing’ to describe how the fragmentation of production brings about new, more collaborative relationships between customers and suppliers. Following the footsteps of Alfred Marshall (1890), Penrose (1959) explained how certain strategic capabilities within enterprises encouraged them to pool resources with other organizations so as to access knowledge complementary to their own knowledge base. Richardson (1972) then explained why these collaborations were important, and the role they play in industrial organization:

> Firms are not islands but are linked together in patterns of co-operation and affiliation. Planned co-ordination does not stop at the frontiers of the individual firm but can be effected through co-operation between firms... inter-firm co-operation is concerned very often with the transfer, exchange or pooling of technology... new products also frequently require the co-operation of firms with different capabilities (Richardson 1972: 888-95).

Sharing of resources allows firms to rationalize innovation process through spread of high costs and risks involved in innovative activities, thereby permitting the exploitation of economies of scale and scope (Nonaka, Toyama and Nagata, 2000). It also facilitates the learning process within firms by providing a way for them to observe how other firms perform and better access to specific project-based knowledge, as pointed out by Dodgson, 1993.

There are many different varieties of cooperative arrangements. Narula (2003) describes how they vary from wholly-owned subsidiaries with full internalisation of transaction, across various types of equity and non-equity agreements, to spot market transactions, where independent firms engage in arms-length transactions. Powell and Grodal (2005) emphasize the importance of informal-non-contractual innovation cooperation, such as common membership in a professional or trade association, participation in ad hoc industry committees, or executive education programs, conferences, mobility, common educational backgrounds etc. The distinction of organisational modes of innovation cooperation is also important, since they produce different impact on participating firms' innovation activity. Granovetter's (1973; 1983) explains how weak ties serve more as bridges to novel information where there is a rapid exchange, while strong ties are useful for social control and the exchange of tacit knowledge.

While the existence of collaborative networks is not new, the rise to prominence of ICTs has encouraged the development of global innovation networks. Freeman (1991) coined the term "networks of innovators" to describe the kinds of networks that facilitate knowledge flows both within and between enterprises and organizations, irrespective of national borders. There are many different types of innovation networks that involve enterprises collaborating with each other or with other organizations. DeBresson and Amesse (1991) indentify at least five different types of innovation networks: supplier-user networks, networks of pioneers and adopters within the same industry, regional inter-industrial networks, international strategic technological alliances in new technologies, and professional inter-organizational networks that develop and promote new technologies. Tidd (2006) developed a typology of innovation networks: new product or process development consortium to share knowledge and perspectives; sectoral forum to adopt and develop good innovative practice; new technology development consortium to share knowledge on newly emerging technologies; emerging standards around innovative technologies; supply chain learning by sharing innovative good practice and possibly shared product development; clustering to exploit innovation synergies; and topic network to explore new technologies.

Innovation networks can be more formal and ridged, usually encompassing a collaborative agreement or strategic alliance with long-term objectives, or they can be informal, flexible and trust-based relations, often linking enterprises with various local actors (Camagni, 1991; Lundvall and Borras 1997). They often form, as Ahuja (2000b) points out, because enterprises need certain kinds of technical knowledge they are unable to generate themselves, or as Imai and Baba (1991) suggest, for triggering continuous interactive innovation. Innovation networks are also path dependent, as pointed out by Granovetter (1983), often reflecting existing relationships and network capabilities. Enterprises generally benefit from being part of an innovation network by sharing the risk and uncertainty intrinsic to the innovation process, gaining access to access to new markets and technologies, speeding up the process of bringing new products to market, pooling complementary skills; protecting property rights when incomplete contracts; and providing access to external knowledge (Pittaway, et al. 2004).

Imai and Baba (1991) identify three strategies that underlie global innovation networks. One strategy, called the traditional multi-domestic network, is typical of the traditional manufacturing industries, which rely heavily on technology coming from suppliers of equipment and materials. The second strategy, called the globalization strategy, comprises planned internalization by multinational enterprises, which consider their market to be global, but try to coordinate production, marketing and R&D activities from a central decision making system. Innovation networks of this kind are generally organized by a multinational enterprise, with both weak and strong connections between constituent members, which may or not be a wholly owned affiliate. A third strategy involves self-organizing networks, which contain joint ventures, collaborative agreements and long-term cooperation that that includes cross-licensing, outsourcing, joint R&D and other types of innovative activities.

Dittrich (2004: 35) argues that global innovation networks should be regarded as systems that can be either closed or open. In a closed network, all enterprises are connected, with norms and sanctions well understood, which allows for knowledge to flow freely between its members. Path dependencies tend to focus its member on preserving existing capabilities of the firm. Enterprises in an open network are not extensively connected to the network, which results in a wide range of competencies across its members, but also creates more opportunities for acquiring new technological capabilities. There is some controversy over which kind of innovation network works best. Coleman (1988) suggests that closed networks tend to encourage innovation more than open networks, whereas Burt (1992) suggests that firms should strive to position themselves strategically in gaps between different nodes, so as to become intermediaries, rather than maximizing the number of ties. Shan, Walker and Kogut (1994) suggest that the number of collaborative relationships that a firm is involved in is positively related to innovation output, whereas Ahuja (2000b) shows that improving trust and reducing opportunism creates more cohesive interconnected partners.

Pittaway, et al. (2004) make the point that national innovation systems play an important role in shaping networking activity. Different national specializations (production and R&D activities) and competitive advantages highlight the importance of national innovation systems. The institutional arrangements of the national innovation system set the rules of the game for each node within the innovation network, irrespective of the type of innovation network. Network failure or misalignment can happen if there is general lack of network capabilities, which may include a lack of scale, inter- firm conflict, external disruption too little trust between partners, too much opportunism or a lack of infrastructure (von Tunzelman, 2004). Nevertheless, network relationships with suppliers, customers, and intermediaries such as professional and trade associations are important factors that affect the innovation process and productivity growth.

1.7 International technology transfer networks

Historical analyses show that being part of global technology transfer network and having a sound national innovation system is essential to the growth process (Knell and Radosevic, 2000). Yet, as Reddy and Zhao (1990) point out, almost the entire network consists of transfers between countries already on the technology frontier. Chapter 2 provides some evidence that shows that some countries below the frontier have gained greater access to these networks. Successful catching-up is most often based on extensive technology acquisition from the leaders, and can involve several different modes or methods of technology transfer. The global technology transfer network consists of at least nine different methods of technology transfer: (1) foreign-owned firms; (2) joint ventures; (3) technical assistance programs; (4) technology licensing agreements; (5) imports from upstream suppliers, especially capital goods; (6) exports to downstream customers; (7) research collaboration; (8) subcontracting agreements; and (9) people through education and training. The first four methods comprise the formal modes, whereas the later five comprise the informal modes.

UNCTAD (1990) emphasizes that each mode of technology transfer is not exclusive; the process of taking advantage of a technological opportunity may involve several of these methods, and the sources need not be foreign. Multinational corporations mediate the first two channels, governments and international organizations mediate the third channel, global markets mediate the fourth, fifth and sixth channels, and global production networks mediate the seventh, eighth and ninth channels. The relative importance of each method of technology transfer will depend on the foreign direct investment regulations and attitudes toward foreign ownership, the intellectual property regime, on the availability of technology in the mode, and how well firms in the economy make use of the modes (Dahlman and Nelson, 1995).

Considerable controversy surrounds the effectiveness of each mode of technology transfer in closing the technology gap. Endogenous growth theory provides justification for why technological accumulation is essential for economic growth (Helpman, 2004), but it does not say much about how technology transfer takes place, or which mode is most effective. The national innovation system and the global innovation network play an important role in this context. Radosevic (1999) emphasizes that the institutional arrangements supporting the national innovation system are important for understanding the specific circumstances and differences in the effectiveness of each mode across firms, industries and countries as well as across time. Reddy and Zhao (1990) emphasize that the opportunity to gain access to global technology transfer network is context specific and depends on several factors including the competition among supplier firms, its importance to the firm supplying the technology, the age of the transferred technology, and the nature of the transferred technology. Davidson and McFetridge (1993) found a close relationship between the mode of transfer and the characteristics of the technology, the parent firm and certain demographic and geographic characteristics of receiving countries. Dahlman, et al. (1987) discovered that the benefits gained from each transfer depend more on how the method is implemented, and not so much on the actual mode used to transfer the technology.

Governance of the global technology transfer network relates closely to the issue of corporate governance as enterprises are always faced with the choice of which method of technology transfer to use. Coase (1937) and Williamson (1975) developed the idea of transaction costs to explain how and why market-failures can lead to more collaboration and strategic alliances. It becomes a strong theoretical argument for the existence of international production is the presence of market failures in technological transactions, as Williamson (1981) maintained. The approach, however, focuses on the allocation of resources rather than the creation of resources such as knowledge, experience and skills (Richardson, 1972). The modes of governance of the global technology transfer network are contingent on markets, technology and customer characteristics, with markets being a cyclical component and technology and demand a longer term, structural component. Hollingsworth (1993) develops a typology of governance mechanisms that suggest a certain range of action depending on whether the degree of network coordination and control.

1.8 The role of multinational enterprises in global innovation networks

Multinational enterprises are often seen as important catalysts for international technology transfer and local spillovers. They have the potential to play an important role in creating, controlling and transferring technology through its own network of affiliates as well as with strategic alliances with other enterprises and organizations (Dunning, 1993; OECD, 2002). Their importance lies not only in providing new machinery and equipment, access to better materials, and methods of production, but also new business practices, management systems and organization of work (Damijan and Knell, 2005). Technology transfer can result in externalities or spillovers to through both formal and informal network relationships, competition, imitation and training. The presence of multinational enterprises can also have a negative effect if competitive pressures force domestic enterprises to close down because they cannot obtain the necessary financing for upgrading their technology.

Multinational enterprises can transfer knowledge in two ways: (1) directly to the affiliates under their ownership and control; and (2) indirectly to other firms in the host economy through externalities, known as knowledge spillovers. Knowledge accumulation can occur in a foreign affiliate after the direct transfer of capital goods, people, licensing agreements and other important network contacts by the parent firm. The absorptive capacity of the affiliate will then determine the pace of knowledge accumulation within the firm. These direct effects can appear as rapid changes in productivity and exports. Technology transfer to an affiliate can also increase technological learning and technical change in local firms directly through subcontracting, collaboration and migration, and more indirectly through competition and demonstration or imitation effects.

There is an important relationship between the two ways to transfer knowledge. Zanfei (2006) argues that the combination of traditional asset exploiting objectives with increasing asset-seeking activities entails a transition of a multinational corporation towards a double network structure. Multinational corporations are increasingly characterised by the interconnection of a large number of internal units that are deeply involved in the company’s use, generation and absorption of knowledge. But units belonging to the internal framework tend to develop external networks with other firms and institutions that are located outside the boundaries of the multinational corporation, in order to increase the potential for use, generation and absorption of knowledge. Each of the external actors with which multinational corporations are interconnected across countries are themselves involved in extensive webs of relationship with other firms and institutions. By becoming embedded in different local contexts, multinational corporations act as bridging institutions connecting a number of geographically dispersed economic and innovation systems.

Collaborative agreements between the parent of the multinational enterprise and its affiliates located abroad can be important not only for generating new knowledge, but also for transferring technology within the enterprise, learning from other enterprises inside the network and utilizing externalities (spillovers) generated by enterprises that are not part of the network. Cantwell and Molero (2003) propose that the type of subsidiary is an important determinant of the intensity of cooperation in innovative activities by foreign subsidiaries with other enterprises located in the host economy. Competence-creating subsidiaries tend to be more integrated into local innovation networks than competence-exploiting subsidiaries. This is because the ability of the competence-creating subsidiaries to fulfil their role depends on their embeddedness in local networks with other firms and other institutions. Vinding (2002) suggests that domestic partners in networks have a greater positive impact on innovative performance than foreign partners. This is in line with the idea that the extent of interaction between the technological activities of firms tends to rise as geographical distance falls suggested by Cantwell and Molero (2003). Other partner specific characteristics of innovation cooperation, as documented in the literature are that diversity of network ties has a positive influence on firms' innovation activity, that firms with central location within networks generate more innovative output (Powell, et al., 1999), and that alliances with direct competitors have a negative effect on innovation (Baum, Calabrese and Silverman 2000).

Knowledge spillovers to the local economy can occur because of technology upgrading of an affiliate by the parent firm to a level that is typically better than found in the rest of the economy and that the parent firm is unable to fully internalize the value of these benefits (Damijan, et al., 2003; Smarzynska, 2003). They can take place between firms that are vertically integrated with the multinational enterprise or in direct competition with it. Kokko (1992) and Perez (1998) suggest that local spillovers have the potential to increase technical change and technological learning in at least four ways. First, greater competitive pressure from foreign affiliates stimulates local enterprises to introduce new products to defend their market share and adopt new management methods to increase productivity. Second, collaboration between foreign affiliates and upstream suppliers and downstream customers increases tends to improve the quality of their suppliers. Multinational enterprises often provide resources to improve the technological capabilities of both vertically and horizontally linked firms. Third, skilled labour can migrate from the foreign affiliate to other local enterprises, providing them with certain capabilities and managerial skills that they may lack. Finally, the proximity of local firms to foreign affiliates can result in demonstration or imitation spillovers. When foreign affiliates introduce new products, processes and organizational forms, they provide a demonstration of increased efficiency to other local enterprises. Local enterprises may also imitate foreign affilaites through reverse engineering, personal contact and industrial espionage.

Dunning (1994) and Bardham (1998) emphasized that not all multinational enterprises transfer knowledge or generate positive spillovers. Multinational enterprises can provide their affiliates with too few, or the wrong kind of technological capabilities, or even limit access to the technology of the parent company. This type of behaviour may restrict the production of its affiliate to low-value added activities and can also reduce the scope for technical change and technological learning in the affiliate. Even if the parent firm transfers new technology to its affiliate, it can reduce the scope for technology spillovers by limiting downstream producers to low value added activities or eliminate them altogether by relying on foreign suppliers (including itself) for higher value added intermediate products. They may even confine production of their affiliate to the needs of the parent firm, restrict exports to competitors, and eliminate local competition by "crowding out" local producers.

1.9 The role of strategic alliances in global innovation networks

Penrose (1959) and Richardson (1972) give emphasis to the need to transfer, exchange and pool resources between organizations to access knowledge complementary to the firms own capabilities. Sharing of resources allows firms to rationalize innovation process through spread of high costs and risks involved in innovative activities, but it also means that enterprises essentially outsource R&D activity. From the enterprises point of view, it becomes a decision to choose between internal R&D activities and external sources of R&D, innovation and technology. Veugelers and Cassiman (1999), however, emphasize that the choice of whether to make or buy is an issue of complementary, and not one of substitutability. This points to the issues of optimal integration of external knowledge and of adequate absorption capacity of the firms using external R&D sourcing. As Cohen and Levinthal (1990) emphasized, own in-house R&D activities are needed to efficiently use the external sources of knowledge. Even more, external linkages facilitate innovation, and at the same time innovative outputs attract further collaborative ties, as Powell and Grodal (2005) point out. Own R&D activity is essential for the firm to enter into a collaborative agreement, both as a prerequisite to join and to gain benefit from the agreement. Freemen (1991), Veuglers (1997), Kremp and Mairesse (2004), Powell and Grodal (2005) and others have shown that own R&D activity is positively correlated with the intensity of networking and it positively affects a firm's ability to exploit the opportunities arising from innovation cooperation. The rate of acquisition of skills and resources from the outside is closely linked to the generation of expertise internally (Powell, et al, 1996).

Global innovation networks have been growing in importance because of the increasing complexity of research, an insatiable desire for new technical knowledge, and heightening global competition. Hagedoorn (2002) and Miotti and Sachwald (2003) provide empirical evidence that shows that the growth of strategic alliances parallels the increase in collaborative agreements and the growing importance of global innovation networks. This may be because strategic alliances and strategic partnerships are complementary to the other modes of technology transfer as Mowery and Oxley (1995) point out. Enterprises have a strategic incentive to become involved in a global network to gain reciprocal access to knowledge, that is, firms share their knowledge to acquire useful knowledge in return. In virtually all cases the partner has to offer knowledge that enhances the existing capabilities of the cooperating firm. This suggests that global innovation networks will likely not reach to countries that are far from the technology frontier.

Enterprises enter into strategic alliances and strategic partnerships to acquire new knowledge and to engage in interactive learning with other enterprises with complementary capabilities. A strategic alliance is a formal relationship between two or more partners who share a commitment to reach a set of common goals by pooling their resources and by coordinating their activities while remaining independent organizations (Hamel, 1991). Strategic partnerships are also a formal strategic alliance, but they do not involve forming a legal partnership. Enterprises often form a strategic partnership when each possesses one or more business assets that will help the other but that it does not wish to develop internally. Hagedorrn (1983) shows that alliances and partnerships have been an important way to share knowledge and other assets particularly in the knowledge intensive industries and in the emerging technologies Powell and Grodal (2005) confirm this trend by pointing out that firms with many prior patents are more likely to form alliances than firms lacking patents. This suggests a recursive process of innovation and growth in which global innovation networks plays a central role.

1.10 Organisation of the report

The report is organized in the following way. Chapter one discusses some concepts and issues related to national innovation systems, global production systems and the emergence of global innovation networks. The chapter following this one provides a comparative overview of the evolution of global production networks into global innovation networks. This chapter finds that knowledge sharing and collaborative learning are prevalent within the European countries included in the study and between Europe and the United States. The CIBS countries have much less access to these networks, but there are signs that knowledge transfer agreements indicative of an innovation network are becoming increasingly more prevalent in all countries, and especially in China and India.

Two large EU Member States are covered in chapters three and four. As the largest member, Germany has a large and diversified science and knowledge-based economy, which appears as a coordinated market economy with certain liberal features that encourages innovation in the private sector. By contrast, the United Kingdom is generally viewed to be a liberal market economy more similar to the United States. The UK has a strong science base and strong innovation capacity in the services sector, but with a relatively low R&D spending relative to GDP in the enterprise sector.

Chapters five, six and seven cover three small Scandinavian countries. All three Scandinavian economies are small, open and dynamic with similar institutional arrangements, but the economic structure each of these economies appears quite different. Denmark has a large number of entrepreneurially based small and medium-sized enterprises; Sweden relies heavily on large knowledge based enterprises; and Norway is a resource-based economy that relies heavily on knowledge based services. All three countries rely heavily on collaborative learning, often jointly with each other, to remain on the technology frontier.

Estonia appears as an interesting case of a catching-up economy in the analysis and is covered in chapter 8. It is a relatively small Member State with relatively low productivity levels, but high productivity growth. It is also has many cultural and linguistic ties to the Nordic countries, and as the report shows, also quite well integrated into Nordic collaborative networks. Having immediate neighbours on the technology frontier with considerable foreign direct investment forced Estonia to be more global in the way it developed its capabilities and accessed markets.

The four CIBS countries are covered in chapters 9 through 12. They show both similarities and differences in their interactions with the EU. There are similarities in that all four countries are relatively large in geographic size and population, the income and wage levels in these countries are significantly behind the European average, income distribution is very unequal, and all four countries are important regional players. They also have distinct political systems, with varying degrees of direct and indirect state involvement in the economy. All four countries are well below the technology frontier, but there are examples where these countries have become global players in certain industries, such as ICT manufacturing in China, ICT services in India and biofuels in Brazil. China and South Africa appear different because of their scepticism toward foreign ownership as a means toward accessing better technology, whereas Brazil and India more heavily rely on multinational activity and embodied technology transfer.

Despite sharing many common features, the individual CIBS countries are fairly heterogeneous, posing quite different challenges and calling for specific policy responses on the side of their partners, especially the EU. The Chinese economy is driven mainly by exports of labour-intensive manufacturing exports and domestic investment in fixed capital. India is a highly diverse economy, ranging from simple handicraft to modern production techniques, and has become a major supplier of labour-intensive manufacturing exports and knowledge intensive services. Brazil is essentially a domestic-oriented service-driven economy, but it has become a major supplier of natural resource-based manufacturers in recent years. South Africa is a bit smaller than the other three, also focuses on agro-based and resource-intensive manufacturers.

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Chapter 2: National innovation systems and globalised Innovation networks in comparison

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2.1 Introduction

The national innovation systems approach to economic performance considers the flow of knowledge and technology among people, enterprises and institutions. It is primarily a systemic methodology that Freeman (1995, 5) defines as “the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.” These institutional arrangements, the OECD (2010, 149) contends, “govern the transfer of various types of knowledge, such as intellectual property, know-how, software code or databases, between independent parties.” Evidence suggests that the “most innovative firms are those with the ability to access outside knowledge and to link into knowledge networks, including informal contacts, user-supplier relations and technical co-operation,” but the OECD (1997, 18) also emphasizes that “they also need the ability to adapt the technology and knowledge to their own needs.” The creation, use and diffusion of new knowledge has become more of a collective endeavour, shaped by institutional arrangements and knowledge-sharing systems.

Lundvall (1988) developed an interactive learning perspective to innovation systems, which considers the interrelationship between the creation and use of technical knowledge to be central to the innovation process. Recurrent interactions generate dynamic capabilities and the kind of knowledge necessary for creating new products and processes. Continuous interactive innovation necessarily involves non-market relationships of a network type. There are many different kinds of networks, but Freeman (1991) coins the term “networks of innovators” to describe networks that are most relevant to the innovation system. Innovation networks represent knowledge flows both within and between enterprises and organizations, irrespective of national borders, but they are also part of the institutional arrangements underlying the innovation system. Camagni (1991) points out, innovation networks can be formal, usually expressed as a collaborative agreement or strategic alliance, or they can be informal or of a tacit nature, often linking enterprises with various local actors. The main reason for being part of an innovation network, Imai and Baba (1991: 389) maintain, is that it enables “corporations to identify emergent opportunities for linking flexible specialisation across the boundaries of firms, and for triggering continuous interactive innovation.” Innovation networks are generally organized with a core enterprise, usually a multinational enterprise, with both weak and strong connections between constituent members, which may or not be a wholly owned affiliate.

Networks of innovators make it possible to transcend national boarders, but they do not replace the institutional arrangements that support the national innovation system. Many enterprises consider their market to be global, despite considerable national diversity, and attempt to coordinate production, marketing and R&D activities from one central location (see Porter, 1990). Some networks evolve in a self-organizing way; containing individual collaborative agreements that facilitate cooperation through cross-licensing, outsourcing, joint R&D and other types of innovative activities (see Imai and Baba, 1991). In a certain sense, the institutional arrangements of the national innovation system set the rules of the game for each node within the innovation network, irrespective of the type of innovation network. Different national specializations (production and R&D activities) and competitive advantages highlight the importance of national innovation systems. Enterprises focus on minimizing costs and gaining the kinds of knowledge that will increase profitability through product innovation. To achieve this goal, many enterprises follow a strategy of building technological capabilities through interactive learning by expanding its international activities, or by entering into an international cooperative agreement, which would make them part of a global innovation network.

Collaborative relationships within the innovation network can take on different forms. These relationships include joint ventures and R&D agreements, technology licensing and exchange agreements, knowledge seeking foreign direct investment, outsourcing, research associations and knowledge banks, government and inter-governmental joint research programmes, and other networks, including various informal networks (Freeman, 1991). Measuring global innovation networks in the national context is a formidable challenge as it involves the distribution of knowledge between different actors and the interactions between them, the extent of innovation and diffusion, and the role that global networks can play in facilitating these processes. Interactive learning and innovation are results of a complex set of relationships among different actors in the system, which includes enterprises, universities, public organizations and governments. An empirical investigation should focus on the explicit cooperative relationships that make up the innovation and complementary implicit relationships that involve trade and embodied knowledge transfers.

This chapter provides a comparative overview of the evolution from global production networks (GPNs) to global innovation networks (GINs) at the national level. It focuses several cooperative relationships as they develop over time in seven European countries, the United States and four of the largest and fastest growing emerging countries: China, Brazil, India and South Africa. These four countries, designated the CIBS countries by UNU-WIDER, have the potential to become southern engines of global economic growth with the possibility to provide prosperity to other developing countries. The seven European countries include three large economies, Germany, Italy and the United Kingdom, three small Scandinavian countries, Denmark, Norway and Sweden, and a small catching-up economy, Estonia. These countries comprise a diverse group of European countries that not only relate to each other, but also to the CIBS countries through various knowledge networks. Estonia is a small European catching-up economy that is closely networked with the Scandinavian countries, but also networked with the CIBS countries. Finally, the United States, with its extensive global innovation networks, is included in the comparative analysis.

The following sections provide a comparative overview of some of the issues important to the national innovation systems when there are globalized networks between technological leaders and catching-up economies. Section 2 provides a summary of the relative importance of China, India, Brazil and South Africa compared with Europe and the United States. Focus is placed on productivity and the importance of innovation. The following section examines the R&D inputs into the innovation system and how actors in different countries relate to the trend. Focus is planed on foreign sources of finance for R&D activity. A comparative approach to competencies, capabilities and technical learning is made in section 4 and considers the important role of absorptive capacity in the innovation network. Section 5 examines the knowledge flows and global knowledge networks between Europe and the CIBS countries. This section will consider the importance of trade in goods and services, foreign direct investment, technology licensing, and mobility of researchers as modes of technology transfer and spillovers. Section 6 will focus on the issue of technological collaboration, emphasizing the role of academic collaboration, research collaboration and innovation collaboration in supporting the national innovation systems. A final section will summarize the findings and put them in the context of the emergence of global innovation networks.

2.2 The relative importance of the CIBS countries

The relative importance of the CIBS countries (China, India, Brazil and South Africa) in the European context has changed considerably over the past 200 years. Table 2.1 shows that in 1820 the CIBS countries accounted for 57 percent of world population and generated about half of the total world income, whereas in 1973 it accounted for a bit more than 40 percent of world population but generated only 11 percent of total world income. By contrast, Western Europe and the United States together accounted for only 12 percent of world population in 1820 and only one percentage point more in 1973, whereas it generated just over 22 percent of total world income in 1820 and almost 45 percent in 1973. In the mid-1970s, three of the CIBS countries were considered 'basket cases' as China and India were mired by famines and bad economic policies, and South Africa was caught in the system of apartheid (Desai, 2008). Only Brazil appeared to have potential, but as the table indicates, even this economy stagnated after 1973.

A noticeable shift occurred between 1973 and 2009. Although the share of world population attributed to the CIBS countries did not change much, their share of total world income increased to almost 28 percent in 2009 from just over 10 percent in 1973. The share of population remained about 42 percent of the global total over the same period. By contrast, the population of Western Europe and the United States fell to under 10 percent of the world total, and their share of world income fell from well over half of total GDP in 1950 to one-third in 2009. When measured in terms of purchasing power parities, China made up a little less than half of the income generated in the CIBS countries, India accounted for just over 42 percent, Brazil another 7 percent and South Africa just under 2 percent. Figure 2.1a illustrates the evolution of GDP in terms of the size of the economy.

Table 2.1. *Western Europe, United States, China India, Brazil and South Africa in the world economy – Share in world population and world GDP, and per capita GDP, 1820-2001*

	1820	1870	1913	1950	1973	2001	2009
Percentage share of world population							
Western Europe	11.0	12.8	12.7	10.5	8.0	5.5	5.1
United States	1.0	3.2	5.4	6.2	5.6	4.8	4.7
China	36.6	28.1	24.4	22.3	23.3	21.5	20.5
India	19.9	17.0	14.2	14.7	15.3	17.3	17.9
Brazil	0.4	0.8	1.3	2.2	2.7	3.0	3.1

South Africa	0.1	0.2	0.3	0.6	0.6	0.8	0.8
Percentage share of world income							
Western Europe	20.5	30.5	30.8	24.4	23.3	18.3	14.3
United States	1.8	8.8	18.9	28.1	22.7	22.5	18.7
China	32.9	17.1	8.8	3.7	3.7	10.2	17.6
India	16.0	12.1	7.5	4.3	3.2	5.5	7.3
Brazil	0.4	0.6	0.7	1.7	2.6	2.7	2.5
South Africa	0.1	0.2	0.4	0.7	0.7	0.5	0.5
Per Capita GDP							
Western Europe	1,245	2,088	3,688	4,906	12,014	20,415	21,368
United States	1,257	2,445	5,301	9,561	16,689	28,727	30,280
China	600	530	552	347	649	2,909	6,592
India	533	533	673	619	853	1,957	3,128
Brazil	646	713	811	1,672	3,880	5,412	6,388
South Africa	415	858	1,602	2,535	4,175	3,982	4,930

Note: Percentages were calculated from estimates of total world population and GDP. The Geary-Khamis dollar, is a hypothetical unit of currency that has the same purchasing power parity (PPPs) that the U.S. dollar had in the United States in 1990. Western Europe includes the 12 most advanced economies: Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Sweden, Switzerland, and the United Kingdom.
Source: Maddison (2006) and own calculations based on The Conference Board Total Economy Database, September 2010.

Real per capita GDP provides a rough indication of productivity and how successful the CIBS countries have been in managing technological and organizational change. Table 2.1 shows that productivity in both Western Europe and the United States increased from about 1,250 $USD to over 21,000 $USD and 30,000 $USD respectively in 2009 when measured in terms of PPPs. This created a widening productivity gap between Europe and the United States with the CIBS countries that only began to close after 1973. But it also indicates that the growth of per capita income in China and India has increased faster than in the Europe and the United States from 1973 to 2009. Using the same Geary-Khamis measure of GDP, but in terms of per person employed, Table 2.2 shows that China and India have experienced relatively high productivity growth since 1980, whereas Brazil and South Africa experienced negative growth on average between 1980 and 2005.

Figure 2.1a shows the evolution of labour productivity per hour for original 15 EU Member States relative to the United States, Norway and Estonia. Data do not exist for China, India and South Africa. The United States, EU-15 and Norway have experienced high productivity growth over the past 30 years and represent the technology frontier. Estonia also experienced high productivity growth, but Brazil appears to have observed little change over the past 30 years. The recent financial crisis appears as a slowdown in growth in the last two years. Figure 2.1b illustrates the catching-up process of the CIBS countries and Estonia in terms of the original 15 EU Member States. This figure shows that China and India have been gradually closing the productivity gap since 1980, whereas it has been widening considerably in Brazil and South Africa. Both figures show that Estonia is rapidly catching-up to the EU-15 average, mainly because of its geographical proximity to the Nordic countries and the 'EU acquis'. Being large countries in terms of population, high productivity growth in China and India has resulted in noticeable growth in the size of their markets and it is expected that the

Chinese market may surpass the EU-27 and the United States in the early part of the 2010s, as shown in figure 2.2.

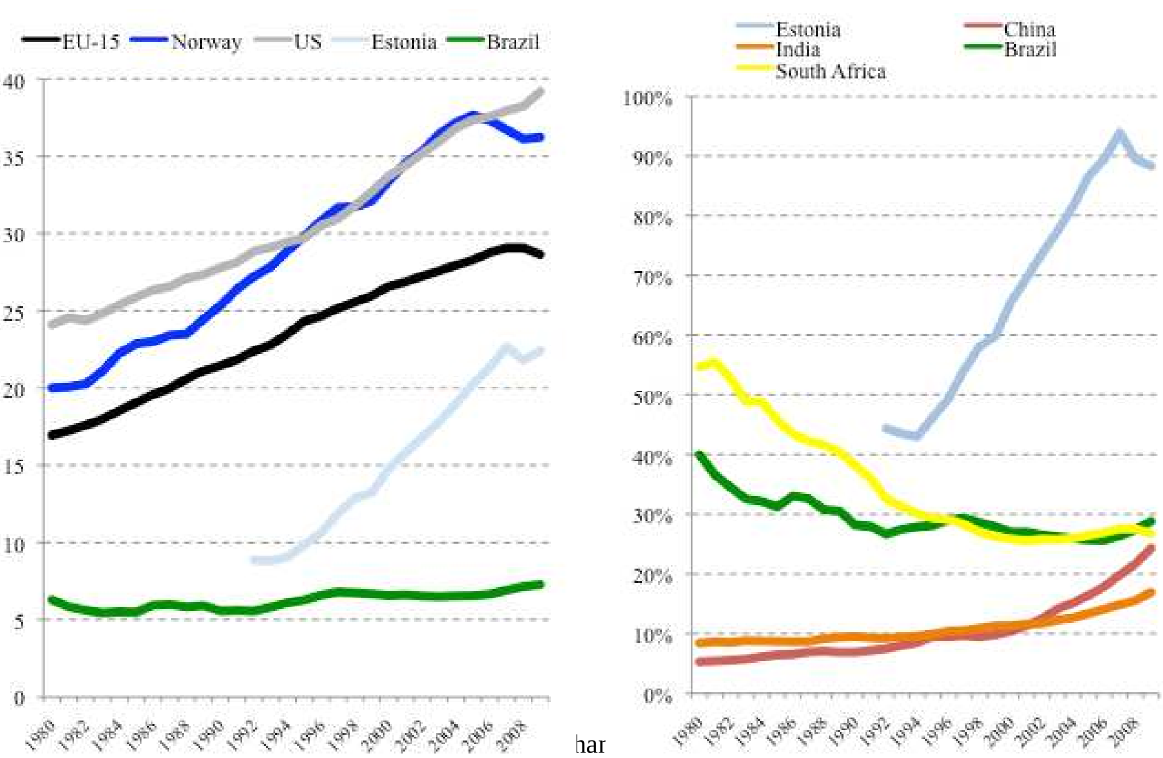
Table 2.2. *GDP per person Employed, in 1990 GK US$*

	1980	1985	1990	1995	2000	2005	2009
Denmark	30,725	34,047	35,865	40,581	44,413	47,151	45,099
Germany	29,060	31,327	34,715	38,500	40,847	42,411	41,617
Italy	34,731	36,903	40,941	45,145	47,247	46,411	44,089
Norway	31,603	35,254	38,044	44,368	48,579	53,470	50,827
Sweden	29,178	31,152	33,129	37,946	43,309	48,914	48,133
United Kingdom	28,753	32,331	34,678	42,411	47,168	50,957	50,966
United States	41,649	45,091	47,907	51,578	58,626	63,792	65,850
Estonia	…	…	20,438	19,165	29,347	40,686	41,032
China	1,655	2,180	2,562	3,941	4,660	7,710	11,296
India	2,638	2,948	3,531	4,111	5,063	6,283	7,866
Brazil	12,500	10,577	10,474	11,656	12,100	12,059	13,393
South Africa	17,099	15,505	14,174	12,150	11,562	12,439	12,446

Note: The data in 1990 international Geary-Khamis US$.
Source: The Conference Board Total Economy Database, September 2010

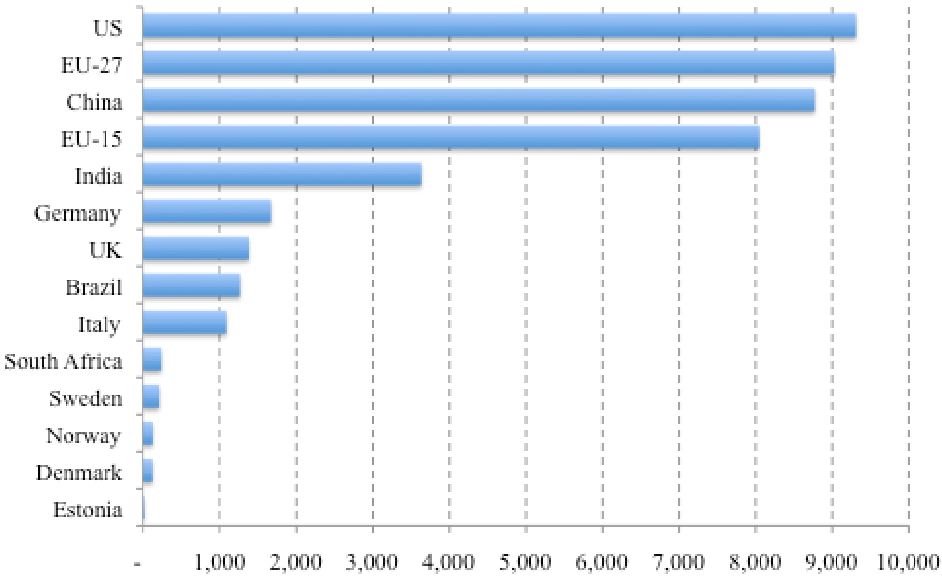
Figure 2.1. *Labour productivity per hour, 1980 to 2009 in 1990 GK US$*

a. Labour productivity per hour *b. Labour productivity relative to the EU-15*



har
US$.
Source: The Conference Board Total Economy Database, September 2010

Figure 2.2. *Relative Size of GDP, 2009 (Billions 1990 GK US$)*



Note: The data in 1990 international Geary-Khamis US$.
Source: The Conference Board Total Economy Database, September 2010

Labour productivity is typically measured as a ratio of output per labour-hour worked or 'average product of labour'. Comparative data, based on the same methodology used in Figure 2.1, exist for the European countries and Brazil, but not for the other three CIBS countries. Figure 2.2 illustrates that the productivity or technology gap between the United States and various European countries is not very significant, indicating that any one of these countries can represent the technology frontier. Estonia also appears to be rapidly catching-up from this point of view. Europe and the United States, however, have much higher 'average product of labour' than Brazil that is also widening, indicating that there is a significant and widening technology gap.

The idea that competitiveness can be applied to a national level is highly controversial, as pointed out by Krugman (1994), but it can be applied to measure how well a country does relative to the others given some criteria. Fagerberg, Sorhlec, and Knell (2007) developed a simple synthetic framework, based on Schumpeterian logic, to measure four different types of competitiveness: technology, capacity, price, and demand. Virtually all studies of national competitiveness focus on the issue of price, or unit labour costs, avoiding the relationship between GDP and technological related factors. The empirical analysis, based on a sample of 90 countries from 1980 to 2002, demonstrated the relevance of technology, capacity, and demand competitiveness for growth and catching-up. Price competitiveness was of lesser importance.

Table 2.3 summaries the four types of competitiveness with respect to the twelve countries discussed in this report. Technology competitiveness refers to the ability to compete successfully in markets for new goods and services. It is a multidimensional indicator that is difficult to measure, often because of a lack of information. In this instance it includes USPTO patent grants, scientific publications and telephone mainlines. The indicator shows that the United States and the Scandinavian countries are the most competitive from this point of view. Capacity competitiveness captures what could be called social capabilities, as defined by Abramovitz (1986), and it includes what this report defines as competencies. This indicator includes three indicators of school enrolment and completion, three indicators captures the quality of governance, and three indicators on financial institutions and markets. Europe scores much higher than the CIBS countries and Estonia, but there is some notable improvement observed in Estonia and South Africa. Demand competitiveness captures the Kaldor’s (1978) idea that the relationship between a country’s production (or trade) structure and the composition of world demand may also be of importance for competitiveness. All countries appear competitive from this point of view, but when related to GDP growth, China and India stand out to have gained the most. Finally, price or cost competitiveness, defined as the growth of unit labour costs in manufacturing in a common currency, captures the potentially damaging effects of excessive wage growth on the economy. This study found a weak relationship between unit labour costs and GDP growth, whereas a strong relationship was found between the other three factors and GDP growth

Table 2.3. Indicators of competitiveness by country

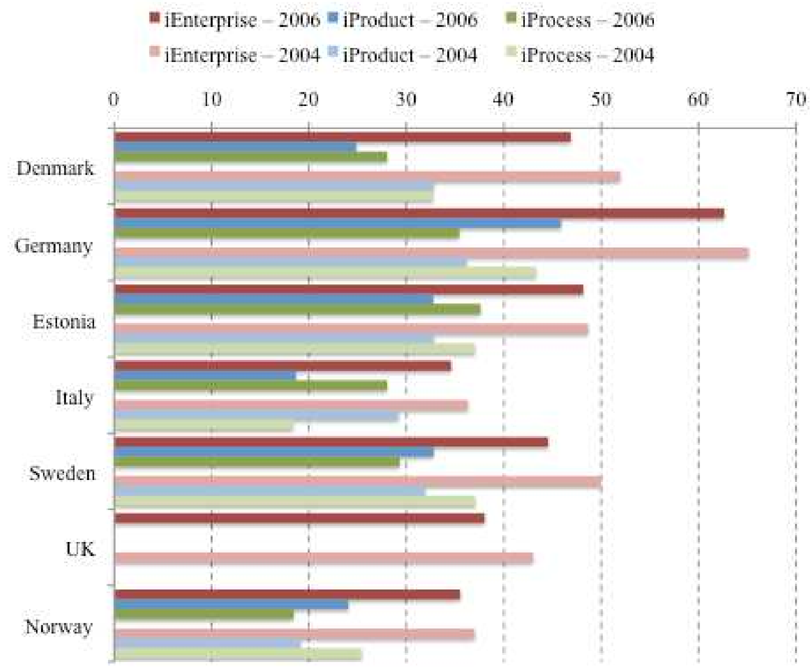
Country	Levels of the composite indicators				Growth of ULC in manufacturing (average annual growth)	Demand Competitiveness (average annual growth)
	Technology competitiveness		Capacity competitiveness			
	1980	2002	1980-2002	7.09	1980-2002	1980-2002
Denmark	1.42	2.49	7.09	6.10	-0.12	7.09
Estonia	-0.73	-0.49	6.10	7.89	…	6.10
Germany	1.10	2.21	7.89	7.66	0.25	7.89
Italy	0.11	0.86	7.66	5.04	2.04	7.66
Norway	0.87	2.00	5.04	7.63	-0.40	5.04
Sweden	2.52	3.62	7.63	7.54	-0.51	7.63
United Kingdom	1.26	1.95	7.54	7.87	-1.34	7.54
United States	2.52	3.80	7.87	6.59	-0.63	7.87
China	-0.74	-0.47	6.59	6.07	-1.15	6.59
India	-0.72	-0.67	6.07	6.52	-1.39	6.07
Brazil	-0.65	-0.30	6.52	4.59	-1.87	6.52
South Africa	-0.49	-0.45	4.59	0.76	-0.06	4.59

Note: Estonia from Fagerberg, Knell and Srolec (2004) and covers the period 1993 and 2001.
Source: and Fagerberg, Srholec and Knell (2007)

Innovation is an important driver of growth in countries on the technological frontier as well as those attempting to catch-up to the frontier. All innovations contain a certain degree of novelty, and depend on business R&D activity in varying degrees. In many cases, enterprises do not perform any R&D activity, but instead rely on different channels of technology transfer to obtain the technical knowledge. Innovation requires, however, that enterprises have the kind of capabilities that allow them to introduce higher quality products, cost-saving processes, and improved organizational and managerial processes. Succeeding sections of this chapter discuss the importance of R&D activity, competencies, capabilities, different modes of technology transfer, and technological collaboration.

Figure 2.3 illustrates the extent of innovation in the seven European countries covered in this report. It covers two surveys, one carried out in 2004 that covers the period 2001 to 2003, and one carried out in 2006 that covers the period 2004 to 2006. Data from the samples show the share of enterprises in the innovation survey sample that have introduced any kind of innovation (iEnterprise), and the share of enterprises that have introduced a process innovation (iProduct) or product innovation (iProcess) during the two periods. They are not mutually exclusive, as the introduction of a new product may also entail the introduction of a new method of production. The table shows considerable differences across countries, which reflect differences in the innovation system and strategic differences of local enterprises. There appears to be a slight decline in the amount of innovation from the first period to the second, but this may be due to differences in the statistical sample and the questionnaire.

Figure 2.3. *Innovative enterprises, product innovation and process innovation, share of total enterprises of survey sample, 2004 and 2006.*



Source: Eurostat Community Innovation Survey 2004 and 2006.

Germany appears to be the most innovative among the countries represented in the figure and Norway appears the least innovative. This may be due to countries with a large proportion of dynamic high-tech industries also had a stronger tendency to innovate, but in the case of Norway it is also be because the survey is compulsory which means that more enterprises that do not innovate will answer the questionnaire. One interesting observation is that Estonia has a high share of innovation, but a low R&D intensity and Sweden has the opposite. There is no discernable pattern between whether product innovation is more important that process innovation and in almost every case the pattern changes from one period to the next.

Product innovation is defined in the survey as a new or significantly improved good or service introduced by the enterprise and process innovation as a new and significantly improved production technology and methods of supplying services (OECD, 2005). This definition, however, does not differentiate between radically new ideas from incremental change, or whether an enterprise creates new knowledge or uses already existing knowledge. Knell and Srholec (2009) proposed to measure the novelty of the innovation by considering the markets those innovative firms interact in. This study shows that research and marketing capabilities is most important in countries on the technology frontier, while process upgrading and foreign ownership make much more difference in countries below the frontier.

Table 2.4 displays the share of innovative firms that operate in local, national, European, and global markets. Enterprises in countries on the technology frontier appear to be more likely to be market leaders in the sense that they operate predominantly on the foreign market and introduce product innovations that are both new to the firm and new to the market, though there does not appear to be a clear pattern when the main market is local or national. When the main market is local, regional, or national they are likely to be competing with already existing products and have a corporate strategy that focuses on absorbing existing technology. This table also shows that there is considerable variation across the different European countries. Since enterprises can answer yes to more than one of the questions, the answers do not add up to 100 percent. But there the table indicates that 11 percent and 25 percent of the enterprises in each country operate in global markets, and it is reasonable to assume that the innovation is planned for this market. The table also shows the percentage of enterprises that are part of an enterprise group and those with a head office abroad. One can assume that difference between the two would identify domestic multinational enterprises, but they can also be a domestic enterprise with more than one facility. The table also indicates that about 15 percent of European enterprises have some form of innovation collaboration with other enterprises and organizations, which will be elaborated on in section 6.

Table 2.4. *Background of innovative enterprises in Europe*

	Main Market:				Enterprise	Head office	Innovation
	Local	*National*	*European*	*Global*	group	abroad	collaboration
Denmark	51.9	46.5	35.1	24.7	30.6	13.3	13.0
Germany	26.9	45.2	29.7	18.3	36.7	4.8	15.8
Estonia	31.0	38.6	34.3	15.3	19.1	8.6	15.9
Italy	17.6	26.2	18.6	11.3	7.9	2.0	12.8
Sweden	37.9	32.4	30.4	16.6	32.6	21.5	16.6
Norway	9.3	27.3	16.1	11.3	20.3	6.2	14.9

Source: Eurostat Community Innovation Survey 2004 and 2006.

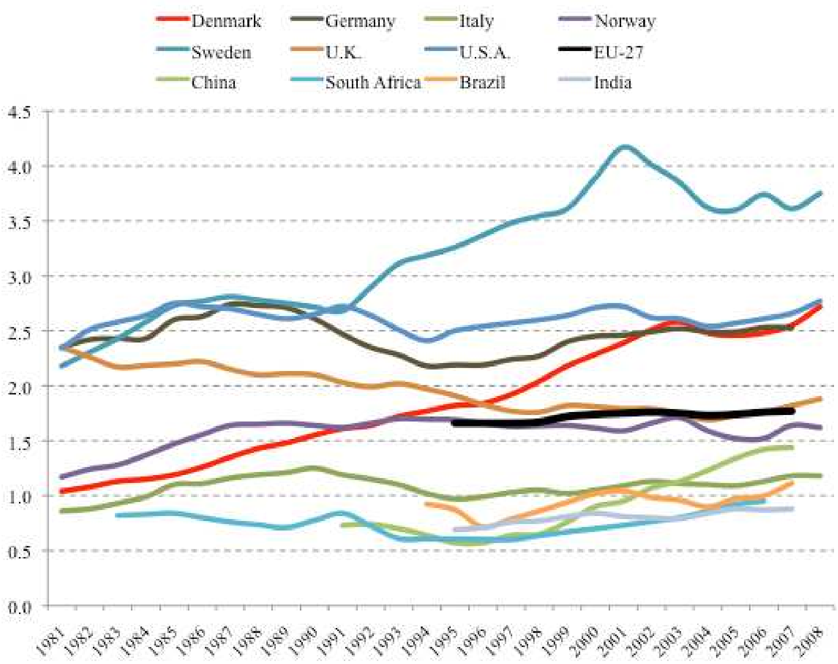
Virtually all innovation surveys define innovation as a new product or process that is *new to the firm*. It is for this reason that Fagerberg, et al. (forthcoming) believes that innovation appears frequent in countries below the technology frontier. Statistics available for Brazil and South Africa that are contained in these country chapters confirm this belief. Innovative enterprises almost always follow a defensive or imitative strategy in these countries. What may be more important is whether enterprises in these countries follow a passive or active form of technology absorption, as pointed out by Viotti (2002). Innovation is important for firms in countries that are trying to catch-up to the technology frontier, but the nature of the innovation will not be understood without considering the degree of novelty at it relation to the global innovation network will define the nature of the innovation.

2.3 The globalization of R&D and the rise of global knowledge networks

Financial and human resources devoted to research and development (R&D) provides the two most commonly used indicators of inputs into the innovation system. Finance for R&D is generally provided by the enterprise, especially when they are large with organized R&D centres, or by entrepreneurs, capitalists and venture capitalists when the enterprise is small. The government can also be an important player as a source of finance as they can absorb some of the risk involved in highly uncertain projects. While these data do not differentiate between R&D activity performed as part of a R&D collaborative agreement and those that do not, almost all of the R&D financed abroad and performed abroad is related to such an agreement or R&D activity within a multinational enterprise.

Figure 2.4 illustrates the evolution of gross expenditure on R&D (GERD) as a percentage of GDP for the CIBS countries, the United States, and selected European countries. This figure shows a mixed trend over the past 25 years, tending to be pro-cyclical, as the growth of R&D generally follows the same trend as GDP growth and growth in gross fixed capital investment, but with a lag. This may reflect the tendency of investors, particularly in the technology markets, to avoid risky projects that require large volumes of R&D in times of economic downturn. Some noticeable exceptions include a long-term increase in Denmark over the 25 years and in Sweden through the 1990s. There is also a noticeable long-term decline in the United Kingdom, which started to move upward only in recent years. This figure shows that only Sweden has achieved the Barcelona target of spending 3 percent of GDP, but Denmark shows considerable improvement over the decade.

Figure 2.4. *GERD as a percentage of GDP*



Source: OECD MSTI database and national sources

As a cross section of countries in the global economy, there is a clear positive relationship between R&D intensity and per-capita income (Knell, 2009). The reason is that R&D expenditures are associated with a certain level of overall economic development and whether this activity is used to generate new knowledge or absorb already existing knowledge. Figure 2.4 shows a noticeable rise in South Africa and China in the 2000s, indicating that some knowledge accumulation is taking place and that they are building the necessary competencies for absorbing technology already available in the global economy. Technological learning is a long arduous process that involves complex and diverse activities between users and producers, and between enterprises, research organizations and the government as the chapters on China and South Africa show.

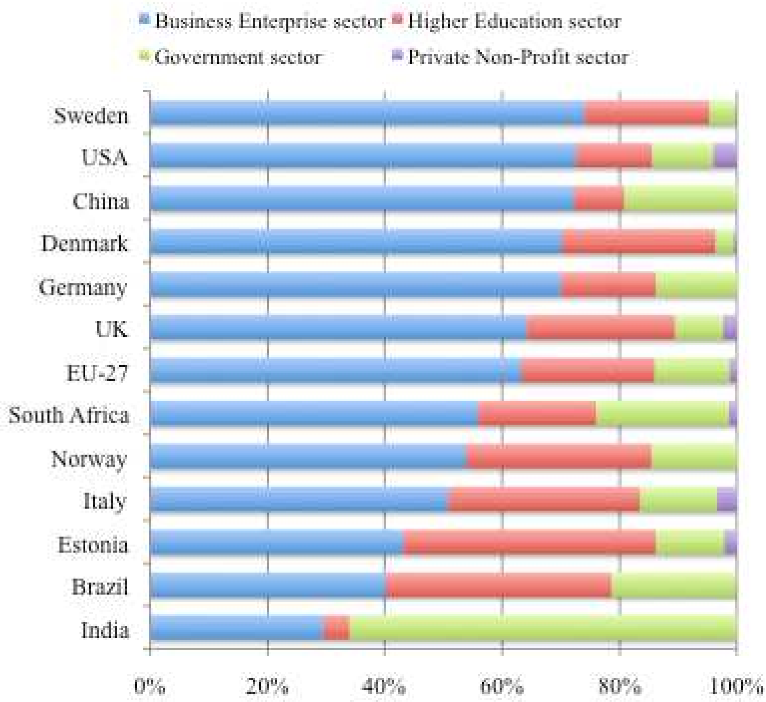
R&D activity involves significant transfers of financial resources within enterprises, and between different enterprises and organisations. Transfers between these sectors tell us something about the structure of the national innovation system and the actors involved in global innovation networks. Table 2.5 presents the breakdown of GERD by sector of performance and source of funds in both 2000 and 2008 for the 27 Member States. It shows that business enterprise expenditure on R&D (BERD) accounts for almost two-thirds of all R&D activity in the European Union, on average. R&D activity of this kind is most closely linked to the innovation activities within a country. This includes all R&D activities carried out in the business sector by performing firms and institutes, regardless of the origin of funding. It funds more than 80 percent of this activity, but it does depend, to an increasing degree, on funding from abroad. This funding often comes from within an innovation network.

Table 2.5. *GERD by sector of performance and source of funds in the EU27 (Millions Euros in 2000 PPPs, 2000 and 2008)*

Sector of performance ***Source of Funds***	All sectors	Business enterprise sector	Government sector	Higher education sector	Private non-profit sector
2008					
All sectors	199,029	125,981	25,918	45,102	2,029
Business enterprise sector	108,393	103,070	2,263	2,853	207
Government sector	67,724	9,277	21,340	36,433	673
Higher education sector	1,968	61	75	1,808	24
Private non-profit sector	3,181	155	496	1,638	893
Abroad	17,763	13,417	1,744	2,369	233
2000					
All sectors	159,831	102,207	22,825	33,533	1,265
Business enterprise sector	88,614	84,833	1,467	2,134	180
Government sector	56,295	8,341	19,913	27,672	369
Higher education sector	1,010	22	41	920	27
Private non-profit sector	2,414	196	318	1,356	543
Abroad	11,498	8,816	1,086	1,451	146

Source: Eurostat database, May 2010.

Figure 2.5. *Percentage of GERD performed by sector*

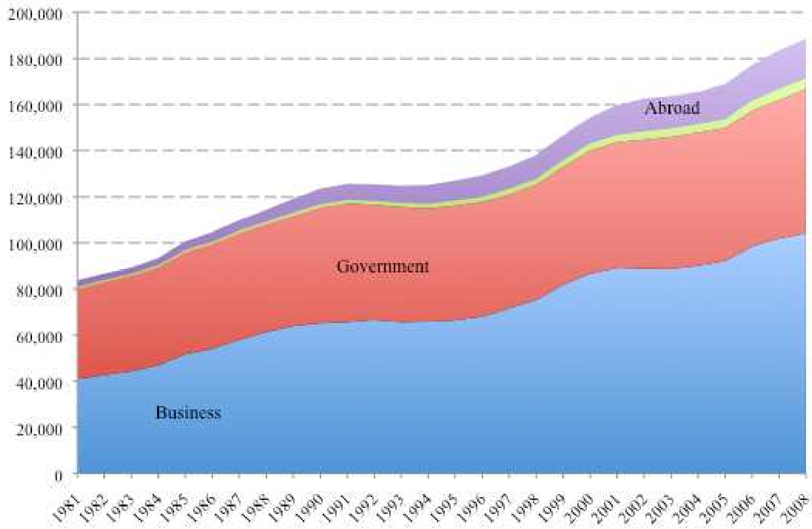


Source: OECD, MSTI database 2009:2 and other national sources.

The government plays an important role in financing R&D, which is mainly performed by business enterprises and by higher education and research organizations. Higher education and the government performed about 21 percent and just over 14 percent respectively. Researchers in the higher education sector tend to do basic and applied research whereas those in the business sector are mainly involved in experimental development. The government is more actively involved in funding the first two types and the enterprise in funding the second two types. Chapters in the report show that the levels and structure of R&D expenditure, and who finances these activities, differ considerably across countries. Figure 2.5 illustrates some of the diversity in terms of the percentage of GERD performed by each actor for both the European countries and the CIBS countries.

Figure 2.5 also illustrates the evolution of gross expenditure on R&D by source of funds in the 15 original Member States. About 95 percent all R&D activity in the European Union Member States, but it also reveals that R&D funding from abroad has increased considerable during the last 25 years, increasing from just under 0.3 percent of GDP in 1983 to over 9 percent of GDP in 2008. This trend indicates that the relative importance of foreign multinationals and the domestic production of technology have been increasing in importance in the European economy over the past 25 years.

Figure 2.6: *R&D expenditure by source of financing in the original 15 EU Member States*

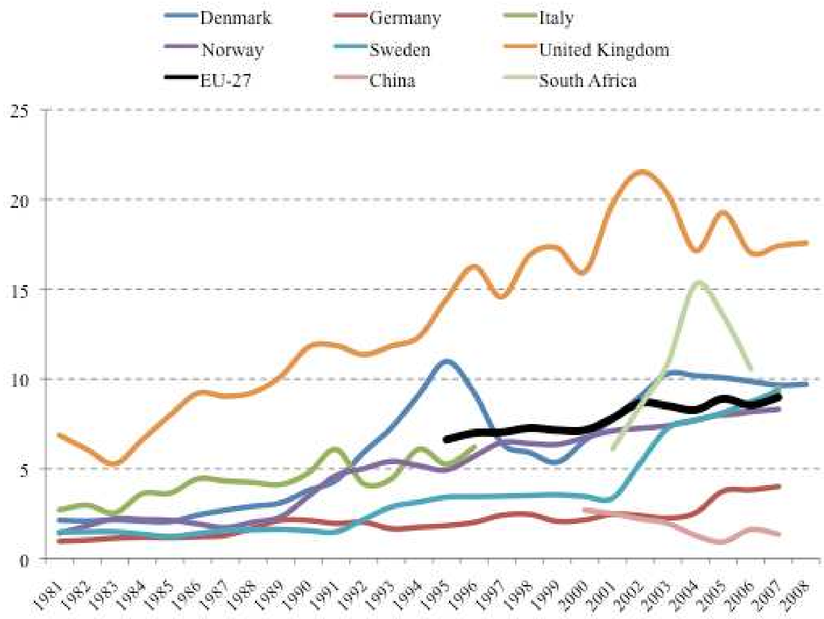


Note: Millions Euros in 2000 PPPs.
Source: OECD, Main Science and Technology Indicators, December 2009 and Eurostat.

Figure 2.6 illustrates the emergence of a global innovation system from the viewpoint of the source of finance for R&D activity. The table also breaks down the R&D sourced abroad by sector of performance. Financing of business enterprise R&D from abroad comes mainly from other business enterprises in the most advanced countries of the European Union. The OECD (2009) observed that in countries where data are available, intra-company funding accounts for about two-thirds of funding from business sources abroad. In European catching-up economies, such as Estonia, the European Commission will play a relatively important role in funding R&D activity. While this table reveals that the growth of R&D activity funded from abroad has increased by almost two percentage points, the relative importance of the business enterprises, government higher education, and private non-profit sector has not changed very much.

Both figures 2.6 and 2.7 illustrate the increasing importance of R&D expenditures financed abroad. R&D that is financed abroad includes all individuals, enterprises and organizations located outside the political boarders of a country (OECD, 2002). Figure 2.7 also shows that there are significant differences across both countries and time in the share of R&D financed abroad. It reveals that R&D expenditures more than doubled in most countries from 1981 to 2008, ranging from about 2 percent in China to almost 18 percent in the United Kingdom in 2008. The rapid growth of UK R&D activity financed abroad was mainly due to large foreign R&D investments in private enterprises, 71 percent of which is in pharmaceuticals, aircraft production and computer services, as well as in research performing higher education institutions (Eurostat). Figure 2.7 also shows that the share of R&D expenditures financed abroad has steadily increased in Europe as a whole from 1994 to 2007, reaching about 9 percent on average. There is little data for the CIBS countries, but data that do exist shows South Africa in the double digits and China having a very low share.

Figure 2.7: *Percentage of GERD financed by abroad*



Source: OECD, MSTI database 2009:2 and other national sources.

R&D activity performed abroad is covered in more detail in section 5 because it is more closely related to the role played by multinational enterprises in facilitating knowledge flows and global networks. All R&D activity in Table 2.5 are intramural expenditures, which are performed within a particular country. The OECD (2002: 108) defines these as "expenditures for R&D performed within a statistical unit or sector of the economy during a specific period, whatever the source of funds." The OECD (2002: 118) defines extramural expenditures as "the sums of the unit, organisation or sector reports having paid or committed themselves to pay to another unit, organisation or sector for the performance of R&D during a specific period." This includes R&D activity performed abroad, but financed by domestic institutions. Norway is one of the few countries to publish extensive data on extramural R&D expenditures performed abroad, which is covered in chapter 6, but some important information can be obtained from the patterns of R&D activity among foreign affiliates, which is covered in section five.

2.4 Competencies, capabilities and learning in comparative perspective

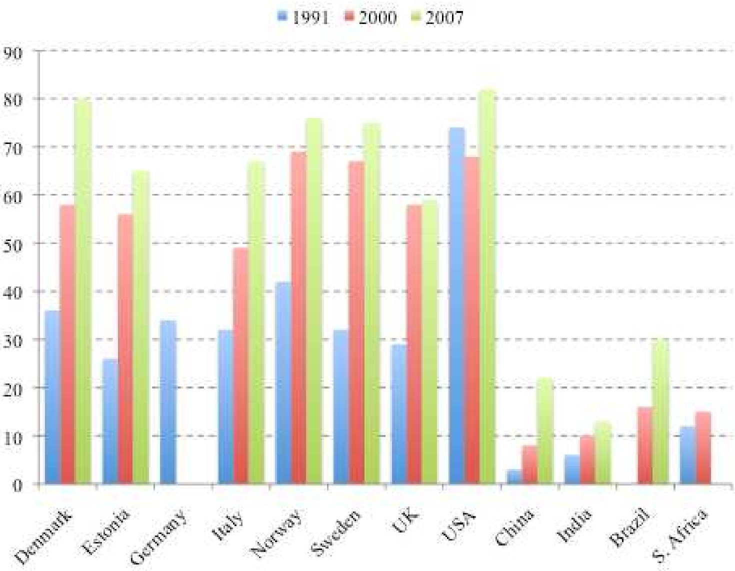
There is often confusion in the literature as to what is meant by 'capabilities' and 'competencies'. In this report capabilities indicate the achieved innovative performances and competencies represent the potential to carry them out (von Tunzelmann, 2009). Dynamic capabilities are distinguished from static capabilities in that they draw on assessments of interactive capabilities and real-time responses (von Tunzelmann & Wang, 2003). While this report describes this distinction in different ways, it limits 'competencies' to indicators of accumulated achievement, without specific reference to the task in hand (e.g. human capital measures based on educational background) and denoting 'capabilities' as the ability in terms of both circumstances and skills to carry out the tasks under consideration (e.g. to implement technical change). Competencies therefore indicate the potential to execute innovative tasks without saying anything directly about whether firms use this potential. There are various indicators that capture competencies, but because capabilities are achieved performances, they need to be measured indirectly and preferably through the use of physical quantities.

Education can provide the potential to create and absorb new technology and are therefore a good indicator of competencies. Nevertheless, the institutional arrangements of the educational system and the level of effectiveness of education policies can constrain the process. Education is an investment in human skills and competencies that, over time, become part of the knowledge base, or social capabilities, of a country. Building competencies in the CIBS countries is key for them to develop the capability to absorb already existing technology and to apply this to the development of new product, processes and organizational forms. It has also been an important factor in attracting multinational corporations interested in taking advantage of the relatively high skills and low unit labour costs in these countries. General indicators of competencies include various measures of the educational attainment of the population and workforce.

Despite being crude, narrow, and insensitive to differences in the quality of formal education, educational attainment and school enrolment remains the best indicator available of technical competencies. There is not much information about educational attainment for the CIBS countries, except for Brazil, which leaves whereas there is some information about school enrolment for these countries. Figure 2.8 illustrates school enrolment in tertiary education as a percentage of the population of official school age for this level. The figure shows that the enrolment ratio in the CIBS countries is much lower than in the European countries, but that the ratio is increasing in all four of these countries, especially in China and Brazil. A similar trend appears in the European countries, except in the United Kingdom, where the enrolment ratio appears does not change much through the first decade of the 2000s. It even declines in the United States through the 1990s, but in 2007 it was at a level comparable to the three Scandinavian countries.

Table 2.6 provides available information on the number of students in tertiary education per 100,000 inhabitants, the gross completion rate and the percentage of graduates broken down into five disciplines for 2007. The number of tertiary students per 100,000 inhabitants is much lower in the CIBS countries, except Brazil, which compares favourably with Italy. From this point of view Estonia appears to be building competencies to take advantage of global knowledge flows. The gross completion rate is the total number of graduates in ISCED 5A programmes (first degree), expressed as a percentage of the population of the age where they theoretically finish the most common first-degree programme in the given country. From this point of view, the Scandinavian countries have the highest gross completion rate, whereas students in the China and Brazil tend to have a much lower completion rate. Of those that completed the degree programme, a majority of the students graduate either in social sciences, business and law, or in education, health, welfare & other services. Norway and Sweden have the highest percentage of students in health, education and welfare, which is an essential part of the Scandinavian social system, which underlies their national innovation system. Science and engineering averaged just under 20 percent of all graduates, with Sweden, which is the leading performer of R&D activity in terms of GDP, having the highest share of graduates in engineering. The United Kingdom has the highest number of graduates in the sciences, followed by the Estonia and the United States. Again, Estonia appears strong in both science and engineering, whereas Brazil appears weak in both. The individual country chapters explore the issue of building competencies and the role the play within innovation networks in more detail.

Figure 2.8. *School enrolment, tertiary (percentage gross)*



Note: 1998 instead of 2000 for South Africa.
Source: UNESCO database on education

Education can also be considered as a process of life-long learning. Lifelong learning includes all purposeful learning activity, whether formal or informal, carried out on an ongoing basis with the aim of improving knowledge, skills and competence. The regular system of schools, universities and colleges provide formal education and training at the primary, secondary and tertiary levels. Non-formal education and training includes all types of taught learning activities that are not part of a formal education programme. Informal learning corresponds to self-learning, which is not part of either formal or non-formal education and training. This may include the making use of printed material, such as professional books, magazines etc.; computer based learning, including online internet based web education; and making use of educational broadcasting, audio or video media, and visiting libraries, learning centres, etc.

Table 2.7 provides an overview of the European participation in life long learning activities by age group. These data were collected as part of a European wide initiative to better understand the importance of different kinds of learning in different national settings. As expected, people tend to become less active in educational activities as they get older. Perhaps more importantly, a much higher percentage of the population of Denmark and Sweden are active in life-long learning activities, with almost 80 percent of the population in Denmark and 71 percent in Sweden. A very low percentage of the population are involved in formal education activities, except in the 25 to 34 year category, but participation in informal learning tends to remain high and above the EU average in all countries, except Estonia. This high involvement in different learning activities may explain the relatively high competencies found in Scandinavia and points to the importance that learning activates play within an innovation network.

Table 2.6. *Number of students, gross completion rate and percentage of graduates, 2007*

	Number of students per 100,000 inhabitants	Gross completion rate	Percentage of tertiary graduates in:				
			Humanities and arts	Social sciences, business and law	Science	Engi-neering	Education, health, welfare & other services
Denmark	4,275	52	13	32	7	13	33
Estonia	5,114	27	10	36	10	11	31
Germany	…	24	…	…	…	…	...
Italy	3,448	41	15	32	7	14	29
Norway	4,603	46	10	28	8	7	47
Sweden	4,540	42	6	25	7	17	44
UK	3,901	39	16	30	13	8	30
USA	5,809	35	13	38	9	7	32
China	1,919	11	...	...	...	...	..
India	1,295	...	...	...	...	...	..
Brazil	2,773	19	3	38	7	6	39

Note: Based on the International Standard Classification of Education (ISCED). Gross completion rate covers INCED 5A.
Source: UNESCO database on education.

Table 2.7. *Participation in life long learning activities by age group, 2007*

GEO/AGE	Total	Between 25 and 34 years	Between 35 and 44 years	Between 45 and 54 years	Between 55 and 64 years
Participation in any learning activities by age					
EU25	42.0	50.2	45.0	40.3	29.5
Denmark	79.7	82.3	83.4	79.9	72.1
Germany	41.9	50.1	44.8	40.9	31.6
Estonia	31.4	41.1	35.8	29.6	15.8
Italy	48.6	57.4	51.5	46.5	35.4
Sweden	71.0	76.6	73.7	71.2	61.9

United Kingdom	37.6	44.1	42.2	38.7	22.5
Norway	34.7	36.7	39.5	35.1	25.2
Participation in formal education by age group					
EU25	4.5	10.7	3.6	2.1	0.9
Denmark	7.7	20.6	6.2	2.9	1.0
Germany	3.4	11.8	1.9	0.6	0.2
Estonia	3.7	11.0	2.4	0.3	0.2
Italy	4.5	12.0	2.5	1.7	0.6
Sweden	13.3	27.2	14.3	8.7	2.8
United Kingdom	8.4	13.3	9.7	6.7	2.6
Norway	3.9	6.1	4.6	3.2	1.0
Participation in non formal education/training by age group					
EU25	16.5	19.8	19.2	16.5	8.5
Denmark	47.1	47.3	52.2	50.2	37.7
Germany	12.7	15.9	15.5	13.2	5.7
Estonia	14.8	17.9	19.0	13.7	7.2
Italy	5.1	5.9	6.2	5.7	2.1
Sweden	48.0	46.0	49.6	51.8	44.3
United Kingdom	34.5	38.5	38.7	36.5	21.7
Norway	32.9	33.7	37.4	33.7	24.7
Participation in informal learning by age group					
EU25	32.5	37.6	34.4	31.4	24.6
Denmark	65.6	65.8	68.8	66.5	60.5
Germany	37.3	42.1	39.7	37.0	30.1
Estonia	25.1	31.0	28.0	26.0	12.9
Italy	46.8	54.3	49.9	45.1	34.7
Sweden	52.6	57.3	53.8	53.0	45.9

Source: Eurostat Life long learning database

2.5 Knowledge flows and global networks between Europe and the CIBS countries

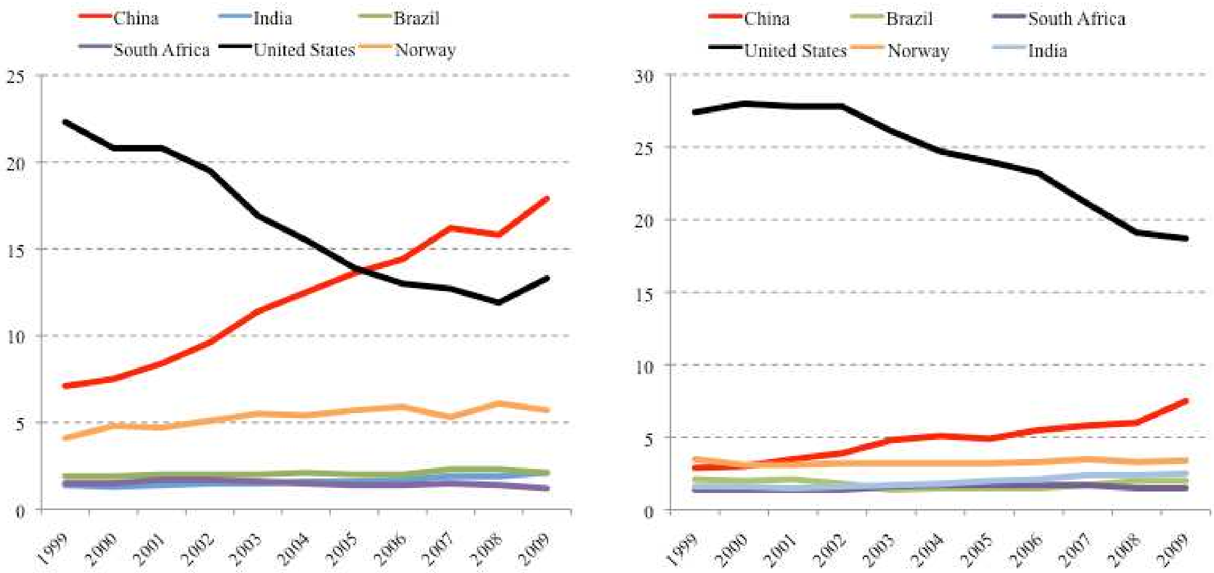
Knowledge flows and global innovation networks are important for countries below the technology frontier that are attempting to catch up with the technological leader, but reverse flows can also be equally important for enterprises located in countries on the technology frontier. In the previous chapter, nine different modes of technology transfer were identified and considered important for facilitating knowledge networks between Europe and the CIBS countries. This section provides empirical evidence for five channels of technology transfer: (1) trade in goods, especially capital goods imports (or embodied technology transfer); (2) trade in business services; (3) foreign direct investment; (4) technology licensing; and (5) mobility of researchers. In this context, own R&D efforts complement technological knowledge obtained from abroad, by providing a way to identify, assimilate and utilise existing knowledge from abroad (Cohen and Leventhal, 1989).

Trade in goods. International trade in intermediate inputs and capital goods embody technical knowledge that was generated through innovation activities carried out abroad. Hoppe (2005) describes three different types of effects that international trade can have on technology transfer. First, imports of machinery and equipment have a direct impact on productivity through the embodied technical knowledge. Imports of knowledge intensive intermediate goods intermediate goods can also have a direct by increasing the variety and quality of inputs. Second, trade expands export markets, encouraging learning-by-doing, improved production decisions and other positive externalities. Third, trade improves access to the global knowledge pool and the availability of new technologies, increasing the scope for reverse engineering and imitation. Technology can also transfer indirectly to other parts of the economy through the generation of externalities or (disembodied) spillovers that arise when enterprises are not able to capture all the benefits implied in the embodied knowledge.

In 2008, extra-EU (27 countries) exports made up 16.6 percent of total world exports, and extra-EU imports made up 19 percent, making it a larger importer and exporter than any single country in the world (see Eurostat). Over the past decade, the share of extra-EU exports in world exports has declined by more than 2 percentage points, whereas the share of Chinese exports has increased by more than 7 percentage points, to make up more than 12 percent of total world exports in 2008. Even more significant declines were observed in the United States and Japan, where the combined share of extra-EU exports in world exports declined by 11 percentage points. The 13-percentage point decline in the Triad’s global market shares coincides with the emergence of the CIBS countries, and especially China, as new players in global markets. Figure 2.9 illustrates the share of exports by partner as a percentage of extra-EU27 trade. Both halves of the figure show the relative importance of China versus the United States. Norway is important for its raw materials.

Figure 2.9. *Share of exports by partner (percentage of EU27 trade)*

a. Imports to EU27 from partner countries *b. Exports from EU27 to partner countries*



Source: Eurostat Comext database

Table 2.8 shows the structure of trade in manufactured products between the seven European countries, the CIBS countries and the United States. As expected well over 50 percent of the imports and exports of the European reporter countries happened within the European Union countries. The United States plays a much more dominate role in China, India and Brazil, especially when the size of the European Union is taken into consideration, and that some countries in the European Union, including Germany and the United Kingdom are important players in South Africa.

Both China and Germany have very high positive trade balances, whereas the United Kingdom and the United States have very high negative balances. This reflects the high knowledge content in Germany and the low wage costs in China, but it is also noticed that trade between China and the United States dominates their respective trade balances. Some trade goes on between the CIBS countries, mainly exports from China to the other countries.

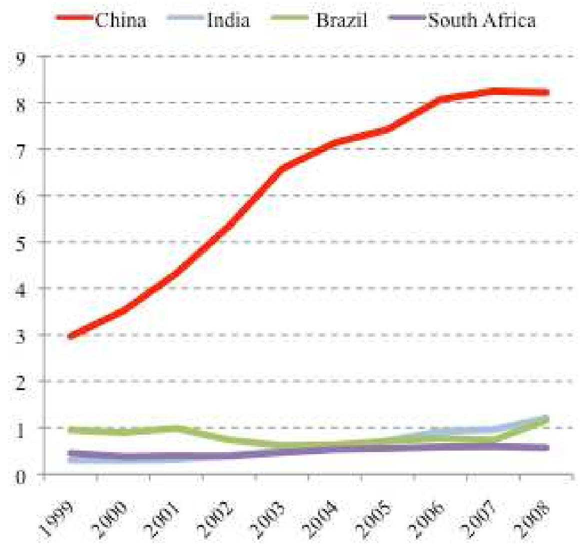
The import of advanced machinery and equipment, and in some cases turnkey plants are another form of embodied technology transfer through international trade. As an indicator of embodied technology transfer, imports of high-technology capital goods represent the demand for new knowledge, and exports from these industries represent the supply of technical knowledge. Figure 1.10 illustrates the evolution of imports of machinery and equipment in the four CIBS countries. The figure shows that imports have risen dramatically in China, but have changed very little in the other three countries. The is not so much a problem for India, as Mowery and Oxley point out,

Table 2.8. *Share of trade in manufacturing, 2007*
(Billions US$ and percent of reporter country trade)

Partner\Reporter	Denmark	Estonia	Germany	Italy	Sweden	UK	Norway	USA	China	India	Brazil	S. Africa
Imports from	***97***	***17***	***1,059***	***512***	***153***	***625***	***80***	***2,017***	***956***	***219***	***121***	***80***
Of which:												
EU-27	73.4	57.5	58.2	57.0	71.7	55.2	68.8	18.0	10.5	13.2	19.4	30.9
Denmark	...	1.6	1.3	0.6	9.1	1.1	6.4	0.3	0.2	0.2	0.3	0.3
Estonia	0.3	0.3	0.0	0.0	0.8	0.1	0.5	0.0	0.0	0.0	0.0	0.0
Germany	21.7	12.0	...	16.8	18.3	14.3	13.6	4.8	4.7	4.0	7.2	11.7
Italy	4.2	...	5.7	...	3.5	4.3	3.3	1.8	...	...	...	...
Sweden	14.5	6.9	1.8	1.1	...	1.7	14.7	0.7	0.4	0.9	1.1	1.4
UK	5.1	3.6	5.6	3.3	7.3	1.1	6.9	2.9	0.8	2.2	1.6	4.8
Norway	4.2	0.8	1.3	0.4	8.5	4.6	...	0.4	0.2	0.5	0.4	0.2
USA	3.5	2.0	5.8	2.9	3.1	8.5	4.8	...	7.3	6.5	15.7	7.7
China	5.7	5.5	7.1	5.8	3.5	7.5	6.0	16.9	9.0	11.2	10.5	10.7
India	0.7	0.3	0.6	0.9	0.4	1.2	0.4	1.2	1.5	...	1.8	2.2
Brazil	0.4	0.2	1.1	1.0	0.5	0.7	1.1	1.3	1.9	0.4	0.1	2.1
S. Africa	0.2	0.1	0.6	0.7	0.4	1.3	0.2	0.5	0.7	1.5	0.4	...
Exports to	***102***	***12***	***1,329***	***500***	***169***	***440***	***136***	***1,163***	***1,220***	***146***	***161***	***64***
Of which:												
EU-27	68.5	64.7	63.3	60.5	60.8	57.5	78.0	21.3	18.4	19.1	22.4	30.8
Denmark	...	2.6	1.6	0.8	7.4	1.0	3.0	0.3	0.4	0.3	0.2	0.3
Estonia	0.3	...	0.1	0.1	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Germany	16.8	4.9	...	12.9	10.4	11.1	11.8	4.3	4.0	3.2	4.5	8.0
Italy	3.3	...	6.6	...	3.2	4.1	2.7	1.2	...	...	...	...
Sweden	14.6	12.5	2.2	1.1	...	2.2	6.1	0.4	0.4	0.3	0.4	0.7
UK	7.9	2.6	7.2	5.8	7.2	...	25.6	4.3	2.6	4.3	2.1	7.7
Norway	6.0	3.2	0.8	0.4	9.4	1.3	...	0.3	0.2	0.1	0.4	0.3
USA	6.4	4.2	7.4	6.6	7.6	14.7	6.0	...	19.1	13.8	15.8	11.8
China	1.8	0.8	3.0	1.7	1.9	1.7	1.1	5.6	...	6.5	6.7	6.5
India	0.4	0.2	0.7	0.8	0.9	1.3	0.4	1.5	2.0	...	0.6	2.1
Brazil	0.4	0.2	0.7	0.7	0.7	0.5	0.3	2.1	0.9	1.3	...	0.8
S. Africa	0.3	0.0	0.7	0.4	0.6	1.0	0.1	0.5	0.6	1.5	1.1	...
Trade Balance	***5***	***–5***	***270***	***–12***	***16***	***–185***	***56***	***–584***	***246***	***–73***	***40***	***–16***

Source: OECD International Trade database

Figure 2.10. *Imports of machinery and equipment (percentage of global market)*



Source: UNCTAD Handbook of Statistics, 2009.

as it prefers to produce investment goods at home and to license technical knowledge to produce them. Imports of machinery and equipment are often accompanied by inward FDI and license and royalty payments abroad because the machinery only contains disembodied knowledge and not the tacit knowledge necessary to understand them. Knowledge flows are difficult to measure in this context because of the quality and complexity of the imported good and the need to import additional knowledge to use them.

Growth in the international trade of intermediate inputs explains partly why global production and innovation networks exist. They occur when multinational firms choose to outsource part of the production process to their foreign affiliates or to another enterprise, resulting in the creation of global production networks whereby each actor is vertically specialized. Vertical specialization can improve the capabilities of the multinational firm to create, absorb and use technical knowledge more effectively, thus creating the possibility of a global innovation network. The reason this happens, as Adam Smith observed, is that production takes place over time in a series of multiple sequential stages and that specialization provides the basis for productivity growth. The specialization process becomes global when the some tasks or stages are performed across national borders. When at least one stage crosses an international border more than once, then it becomes vertical specialization.

A simple way to measure vertical specialization is to use input-output tables. Input-output tables describe the sale and purchase relationships between producers and consumers within an economy. Vertical specialization is the imported input content of exports, or foreign value-added embodied in exports. Table 2.9 shows that the degree of specialization in the

Table 2.9. *The extent of vertical integration in Europe and the CIBS countries (Percentage of import contents of export in each industry)*

	Machinery and equipment		Office machinery		Electrical machinery	
	2000	*2005*	*2000*	*2005*	*2000*	*2005*
Denmark	34.8	37.0	39.8	42.9	42.9	49.1
Estonia	54.0	50.1	72.3	70.7	70.8	65.1
Germany	23.2	24.7	39.3	39.1	22.1	25.3
Italy	25.1	26.8	58.8	57.4	30.3	29.0
Norway	34.8	33.8	56.1	43.1	34.4	34.2
Sweden	33.3	35.6	29.4	35.6	35.7	41.5
UK	24.9	26.1	50.5	36.0	25.4	28.7
USA	14.2	16.4	16.6	17.2	14.0	15.7
China	18.4	25.3	42.8	43.1	22.8	27.2
India	17.0	18.9	17.7	27.8	23.4	23.1
Brazil	8.9	17.0	18.0	43.4	16.4	17.8
South Africa	22.0	24.0	10.6	12.6	20.3	23.2

Note: Machinery and equipment is Nace29; Office machinery Nace30 and electrical machinery Nace31. The Import contents of export is calculated as $uA^m(I-A^d)^{-1}X/X_k$, where A^m and A^d are the input-output coefficient matrices for imported and domestic transactions, respectively, I is the identity matrix, u is a 1xn vector of 1’s corresponding for each import type, and X is the export vector.
Source: OECD Input-Output table database

three machinery sectors is very high in the small countries of Scandinavia, and especially Estonia. They also appear relatively stable in all of the European countries over the two time periods. The extent of vertical integration is relatively lower in the CIBS countries, except for the office machinery in China, but there are also a noticeable increases observed in the machinery and equipment industry in Brazil and China and Office machinery in India.

Trade in services. Although trade in services appears much less important than trade in goods, as measured by both absolute volumes and shares in GDP, it has been growing much faster than trade in goods. Its importance lies in being a mode of transferring tacit knowledge and other knowledge necessary for product and process innovation. In the European Union, trade in goods averages 32 percent of GDP, whereas trade in services average about 10 percent in 2007. Table 2.10 shows the share of service trade between the countries contained in this report plus the EU27 and the United States. The top half of the table provides data on total service trade. This table shows that most trade in services is done between the European countries themselves and the United States. The share of trade in services between the CIBS and Europe is very low. The bottom half of the table shows a similar trend with business services, which are often describes as the knowledge intensive business services or KIBS.

Service trade has been increasing faster in the EU countries than in the United States, and it has been increasing even faster in China and India. As Figure 2.11 shows, China and India have been increasing at an exponential rate, with China increasing relatively faster in the EU and India in the United States. Table 2.10 already indicates that China is the most important service trader among the CIBS countries, accounting for almost half of their trade in services. India has become increasingly important, especially in the United Kingdom, where considerable offshoring of business services to India has happened over the past decade.

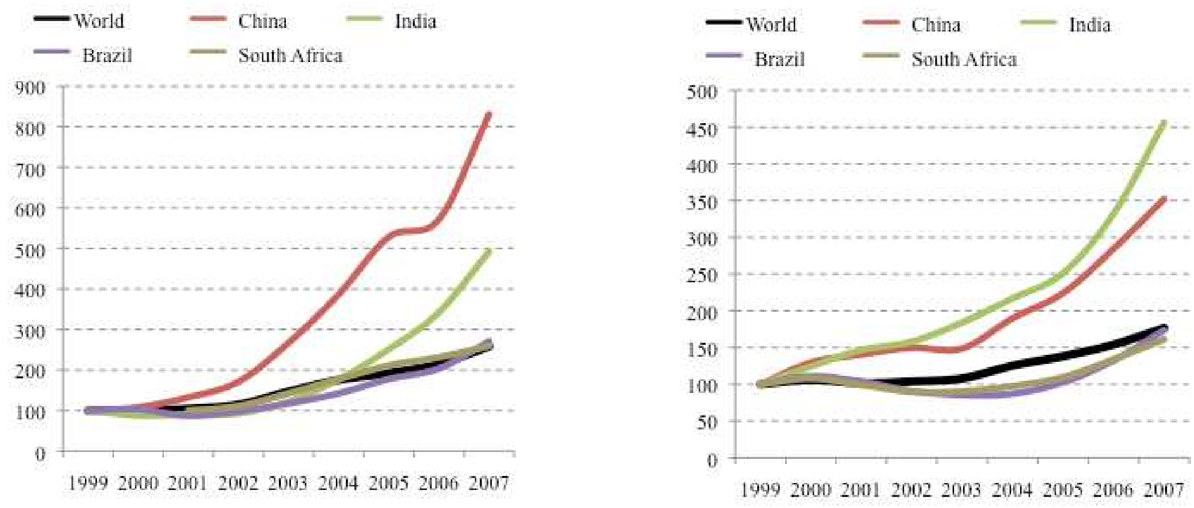
Table 2.10. *Share of trade in total services, 2007 (in percent of reporter country trade)*

Partner \ Reporter	Denmark	Germany	Italy	Norway	Sweden	UK	USA	EU27
Exports of total services								
EU27	48.3	52.6	62.9	59.6	49.7	40.1	36.7	57.7
Extra EU27	51.7	...	37.1	40.4	50.3	59.9	...	42.3
Norway	6.2	...	0.5	...	11.5	1.7	...	1.6
United States	12.8	13.1	9.6	27.8	10.3	21.9	...	11.8
China	4.4	2.0	0.5	0.1	1.4	1.0	2.9	1.5
India	1.4	0.8	0.5	0.1	0.5	1.2	1.9	0.8
Brazil	1.3	0.7	0.7	0.3	0.3	0.3	2.0	0.5
South Africa	0.7	0.7	0.2	...	0.3	1.0	0.4	0.5
Imports total services								
EU27	55.1	58.1	62.3	74.2	62.0	52.2	38.6	60.0
Norway	4.0	...	1.2	...	4.7	1.0	...	1.1
United States	13.4	11.0	8.0	15.2	13.9	16.3	...	12.3
China	2.1	...	1.3	0.2	1.0	1.0	2.3	1.3
India	0.8	...	0.4	0.1	0.4	1.8	2.6	0.7
Brazil	0.6	...	0.7	0.2	0.2	0.3	1.1	0.5
South Africa	0.5	...	0.2	...	0.2	0.9	0.4	0.4
Exports of business services								
EU27	61.6	49.1	71.7	58.5	51.5	...	...	53.7
Extra EU27	38.4	...	28.3	41.5	48.5	...	...	46.3
Norway	7.4	0.4	0.3	...	5.9	...	...	1.3
United States	11.8	14.2	8.2	31.1	11.1	...	...	13.0
China	2.0	2.0	0.4	0.2	1.0	...	...	2.3
India	0.4	0.4	0.1	0.1	1.0	...	...	1.2
Brazil	0.2	0.5	0.3	0.1	0.3	...	...	0.3
South Africa	0.4	0.5	0.1	...	0.4	...	...	0.3
Imports of business services								
EU27	61.5	56.5	71.1	66.3	54.9	...	...	61.5
Norway	6.8	0.5	1.6	...	3.5	...	...	1.1
United States	18.2	15.1	9.6	22.7	23.5	...	...	15.3
China	0.9	2.1	0.9	0.2	2.2	...	...	1.0
India	0.9	1.0	0.3	0.0	0.7	...	...	0.6
Brazil	0.1	0.7	0.2	0.1	0.4	...	...	0.4
South Africa	0.1	0.4	0.1	...	0.4	...	...	0.3

Source: OECD Trade in Services Database

Figure 2.11. *Evolution of trade in services from CIBS countries to the EU and USA*

EU *USA*



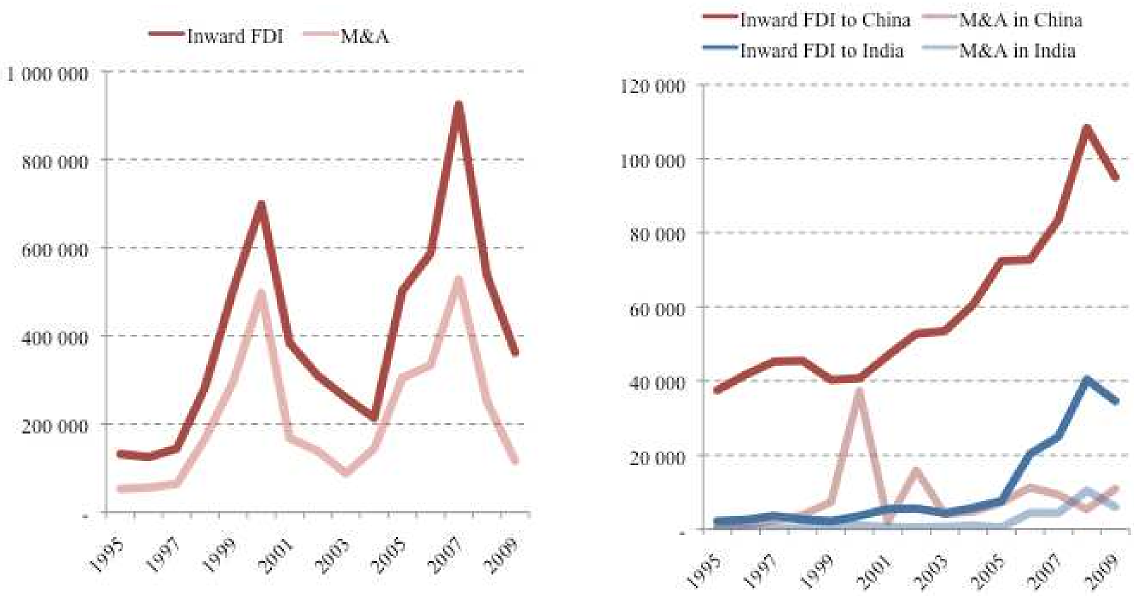
Source: OECD Trade in Services Database

Foreign direct investment. Inward foreign direct investment (FDI) frequently includes a transfer of technology. Certain activities by multinational enterprises can help to shape the speed and direction of the economic transformation of the CIBS countries by transferring technology directly to their affiliates and indirectly to local firms through knowledge spillovers. While the empirical literature suggests that FDI and trade have been found to increase productivity of the receiving country (Keller, 2004), spillovers to the local economy appear to be rare (Hanson, 2001). Dunning (1994) also pointed out that technology transfer might be limited if the parent firm provides their affiliates with too few, or the wrong kind of technological capabilities, or even limit access to the technology of the parent company. What is not well understood in the empirical literature is how technology transfer and knowledge spillovers are related to global multinational networks and hence, global innovation networks.

FDI statistics track the value of cross-border transactions between investors. A vast majority of both inward and outward FDI flows occur between the developed economies of the OECD. The reason is that it rarely contains new investment in machinery and equipment, but rather the purchase and sale of ownership rights. Often large spurts of FDI are related closely with cross-border mergers and acquisitions, which is highly sensitive to the financial markets. Figure 2.12 illustrates the importance that global mergers and acquisitions have on the evolution of inward FDI in the European economy. The two sharp declines coincide with the dot-com bubble and the recent financial crisis. The figure also shows that global mergers and acquisitions are not so important in the Chinese and Indian economies. This trend indicates that most inward FDI is Greenfield investment and related to outsourcing of production activities by foreign multinationals.

Figure 2.12. *Inward FDI and creoss-border mergers and acquisitions*

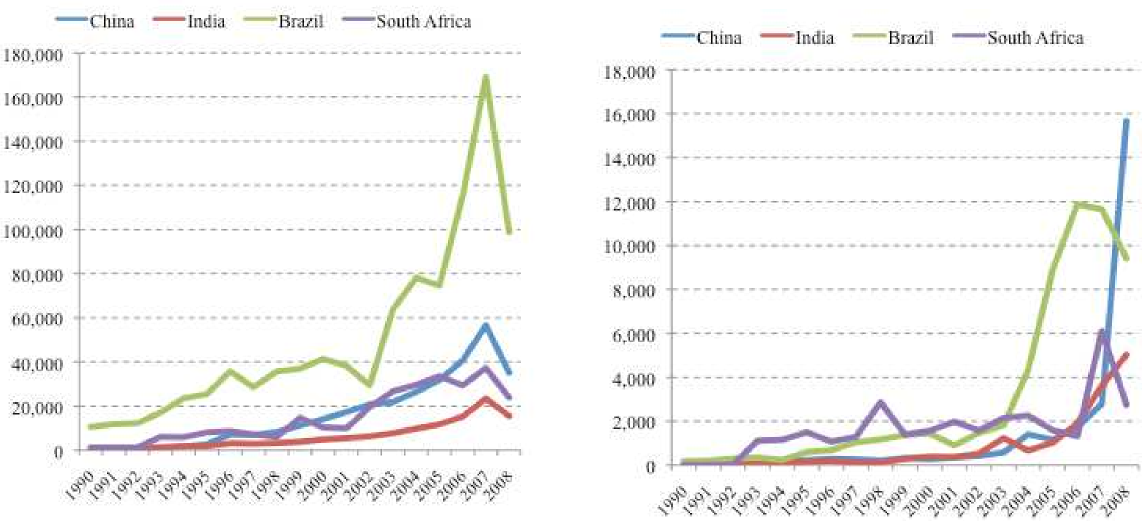
a. Inward FDI into Europe *b. Inward FDI into China and India*



Source: UNCTAD Foreign Direct Investment Database

Figure 2.13. *Evolution of FDI positions in the CIBS countries*

Inward FDI from OECD Europe *Outward to OECD Europe*



Source: OECD Globalisation database

Figure 2.13 illustrates the evolution of FDI position in the CIBS countries relative to OECD Europe, which also includes Norway and Switzerland together with the EU. Brazil is the main recipient of these funds, mainly because of strong interests in the primary sector. Cross-border

M&As in the metals and minerals extractive industry explains the large jump for Brazil (UNCTAD, 2009). Table 2.11 shows how small these flows are when compared with the flows within Europe and between Europe and the United States.

Outward flows from the CIBS countries are about one-tenth the size of the inward flows. They are important nonetheless because they can represent the strategy of enterprises within these countries to seek certain knowledge assets and to create production and innovation networks with the multinational being centred in one of the countries. As Figure 2.12 shows, both Brazil and China experienced large jumps in outward FDI in recent years. The jump in Brazil was partly due to Brazilian firm acquiring assets abroad in mining and natural resource-based activities, and to transfer capital to some of there their financially distressed affiliates abroad (UNCTAD, 2009). China was also acquiring assets in the primary sector, but its recent acquisition of manufacturing firms has created much attention. As with the inward flows the FDI position, Table 2.11 shows that the relative size of the outward flows from the CIBS countries to Europe and the United States is rather small.

The economic activity of multinationals enterprises may provide a more direct measure of global knowledge networks as it focuses on overall operations, such as turnover (sales), employment, and R&D activity, of the foreign affiliate and parent company. These indicators rely on the idea of control and who has the power to strategic choices. Table 2.12 provides an overview of the evolution of foreign R&D activity by foreign affiliates as a percentage of business enterprise R&D in five European countries and the United States. The table shows a clear trend toward globalization of R&D activity, but there also appears to be considerable volatility over time. The share of R&D activity located in foreign affiliates varies from 26 percent to 37 percent in Europe, but is less than half of this in the United States.

Table 2.11. *FDI positions by partner country, 2005-2007 (in percent of reporter country)*

Partner \ Reporter	*Denmark*	*Germany*	*Italy*	*Norway*	*Sweden*	*UK*	*USA*
Inward							
EU27	68.6	28.8	76.9	25.6	67.9	37.6	23.9
Norway	5.4	0.4	0.1	0.0	7.7	0.2	0.5
United States	8.8	12.3	8.9	19.1	14.8	28.6	0.0
South Africa	0.0	0.2	0.0	0.0	0.0	0.1	0.0
Brazil	2.6	0.0	0.1	0.0	0.0	0.0	0.1
China	0.3	0.1	0.0	0.0	0.0	0.0	0.0
India	0.0	0.0	0.0	0.0	0.0	0.2	0.1
Outward							
EU27	60.3	46.0	76.3	23.5	66.0	30.8	19.7
Norway	7.5	0.3	0.1	0.0	6.9	0.4	0.4
United States	10.6	20.6	6.7	13.0	14.2	23.7	0.0
South Africa	0.1	0.5	0.1	0.3	0.3	1.3	0.2
Brazil	0.7	1.1	1.5	1.5	0.9	0.4	1.5
China	1.3	1.6	0.4	0.2	0.8	0.3	1.0
India	0.2	0.4	0.2	0.0	0.3	0.3	0.4

Source: OECD Globalisation database

Table 2.12. *Share of R&D expenditure of foreign enterprises, 1997 to 2007*

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Germany	17.2	...	17.8	...	24.8	...	26.7	...	27.8	...	26.2
Italy	...	...	...	...	33.0	27.7	26.3	25.9	25.2	26.6	...
Norway	...	...	...	...	...	...	25.4	28.2	27.8	28.3	30.5
Sweden	18.7	...	36.4	...	40.7	...	44.7	...	42.3	...	35.5
UK	32.8	30.4	31.2	31.3	42.8	40.7	44.6	40.5	39.1	38.4	37.5
USA	10.9	13.2	13.1	13.0	13.1	14.2	14.9	14.4	13.8	14.0	14.8

Source: OECD, Main Science and Technology Indicators, December 2009.

Table 2.13 provides an overview of Inward activity of multinationals by investing country, total manufacturing turnover for 2007. More than half of the turnover of foreign affiliates located in Europe is attributed to multinationals located in other countries in Europe. The UK is the exception, having strong links to the United States. On the other side, more than half of the turnover of foreign affiliates in the United States is controlled by European enterprises. Some of turnover of foreign affiliates in Europe and the United States is related to the CIBS countries, but the size is relatively small. There is very little data outward activity of multinationals by investing country. Table 2.14 provides some information on multinationals located in Germany, Italy and the United States. This table shows the activities of foreign affiliates located in other countries. Fewer than 10 and 5 percent of the turnover of US and Italian multinationals are attributed to the CIBS countries, with Brazil being the most attractive country. R&D expenditure of the affiliates tends to be located in other developed economies.

Table 2.13. *Inward activity of multinationals by investing country, manufacturing turnover, 2007*

Partner \ Reporter	Denmark	Germany	Italy	Norway	Sweden	UK	USA
World	99,997	523,640	158,624	211,680	727,854	227,393	1,195,807
EU27	68,081	397,090	76,628	119,917	411,796	63,461	658,401
Denmark	...	7,371	771	27,626	36,153	4,248	3,233
Germany	10,499	...	17,110	9,514	41,730	14,737	193,785
Italy	...	15,673	...	917	10,826	5,515	17,291
Norway	5,424	3,754	789	...	45,407	1,519	...
Sweden	...	9,953	5,888	28,537	...	3,064	27,255
UK	14,451	116,032	11,192	17,627	81,127	...	141,151
USA	...	74,966	57,337	50,860	174,145	102,282	35,046
Estonia	...	0	0	0	22	0	...
China	0	128	0	...	0	...	...
India	...	205	119	0	1,185	...	1,155
Brazil	...	...	0	...	...	...	13,762
South Africa	0	...	1,456	...	9	187	0

Note: Data for Germany are from 2006, Italy are from 2005 and Denmark are from 2002.
Source: OECD Globalisation database, activities of multinationals.

Table 2.14. *Outward activity of multinationals by investing country, manufacturing turnover and R&D expenditures, 2007*

Partner \ Reporter	Turnover: Germany	Turnover: Italy	Turnover: USA	R&D expenditures: Germany	R&D expenditures: Italy	R&D expenditures: USA
World	1,486,704	255,784	4,736,009	9,459	198.8	35,019
EU27	646,670	166,262	2,131,648	...	163.8	21,779
Denmark	...	1,489	16,604	...	2.1	151
Germany	...	33,482	313,905	...	39.2	5,970
Italy	...	...	127,723	...	...	668
Norway	...	2,397	41,548	...	7.4	46
Sweden	...	1,942	57,534	...	0.9	1,555
UK	171,313	32,572	625,442	...	10.4	6,522
USA	309,561	24,059	...	...	19.6	...
Estonia	...	23	379	...	...	1
China	...	1,781	117,748	...	0.3	1,141
India	...	643	28,053	...	0.3	449
Brazil	...	10,739	126,839	...	1.8	629
South Africa	...	569	21,436	...	...	53

Note: Turnover for Italy is from 2005 and R&D expenditures for Italy are from 2003.
Source: OECD Globalisation database, activities of multinationals.

Technology licensing. Technology balance of payments statistics measures international transfers of scientific or technical knowledge and assistance. Considered the main form of disembodied technology diffusion, a vast majority of these transactions correspond to operations between parent companies and affiliates. There is conflicting evidence on whether the most advanced technologies transfer through this channel. Mansfield and Romeo (1980) point to empirical evidence suggesting that the technologies transferred to foreign affiliates are newer than those for outside licensing and joint ventures. Athreye and Cantwell (2007) argue that licensing is associated with building technological capabilities.

Table 2.15 contains data on cross-border payments and licence fees for the European Union, 6 EU Member States, Norway, the United States and the CIBS countries for the period between 2005 and 2007. Royalties and payment for license fees make up a large part of the technology balance of payments and are easier to collect because they are included in IMF Balance of Payments Statistics. Royalties are defined as usage-based payments made by one actor to another for a license to use of intangible, non-produced, non-financial assets and proprietary rights. They include payments accruing from patent, trademarks, registered designs, utility models, copyrights and technical instruction. Ownership of the asset is often referred to as intellectual property rights (IPRs). Royalty and license payments capture disembodied technology acquisition, and royalty and license payments receipts capture disembodied technology exports.

The United States was the main exporter of technical knowledge and assistance from 2005 to 2007 and the 27 Member States of the European Union were the second largest exporter. One big difference between the two is that the United States was a large net exporter of disembodied knowledge and the European Union was a large net importer, with all of the individual reporting Member States showing a negative balance with the US. All of the reporting countries had a positive balance of payments with the CIBS countries, except for a very small payment from Norway to India. However, the total royalties and payment for license fees from the CIBS countries to Europe and the United States was relatively small when compared with payments made between countries on the technological frontier.

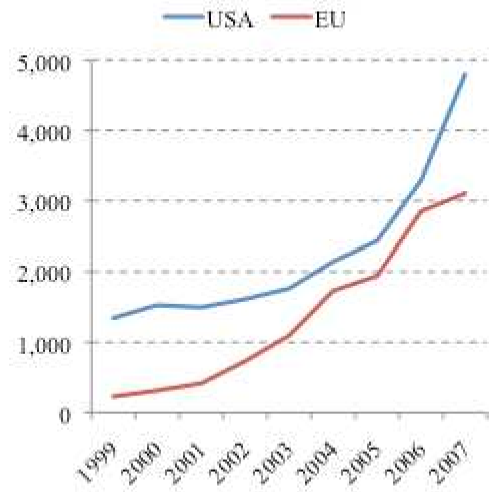
Table 2.15. *Trade in royalties and License fees, 2005 to 2007 (US$ million)*

Partner \ Reporter	EU27	Denmark	Germany	Italy	Sweden	Norway	USA
Exports (receipts)							
World	52,949.4	1,781.0	6,975.0	1,074.6	4,072.5	633.3	73,066.7
EU27	21,397.1	846.0	2,549.7	592.3	1,903.0	237.4	32,234.3
Extra EU27	31,552.7	935.0	...	482.3	2,169.5	450.1	...
Norway	542.0	70.0	27.3	0.0	128.4	...	258.0
USA	12,298.6	203.9	2,143.7	142.2	931.6	358.5	...
China	1,540.7	64.4	214.7	5.7	421.0	0.0	1,522.7
India	288.7	4.6	26.0	7.7	21.7	0.0	481.7
Brazil	390.3	6.1	61.7	22.3	49.6	9.7	1,080.0
South Africa	412.2	0.7	108.3	0.5	7.7	...	420.3
Imports (payments)							
World	69,083.2	1,224.2	8,557.3	1,794.1	1,663.0	527.0	25,048.0
EU27	27,287.1	609.5	3,163.7	1,251.3	784.6	295.5	11,906.0
Norway	214.5	18.7	27.7	0.4	41.8	...	105.0
USA	27,331.6	440.8	3,524.7	350.1	531.5	155.8	...
China	78.0	1.5	74.7	0.4	2.8	0.0	115.0
India	43.0	0.1	8.0	0.4	6.9	0.2	98.0
Brazil	23.1	3.5	5.7	0.0	0.3	0.0	6.0
South Africa	35.8	0.2	3.7	0.0	0.1	...	20.0
Balance (EX–IM)							
World	-16,133.8	556.8	-1,582.3	-719.5	2,409.5	106.3	48,018.7
EU27	-5,890.0	236.5	-614.0	-659.0	1,118.4	-58.1	20,328.3
Norway	31,338.2	916.3	...	481.9	2,127.7	...	...
USA	-26,789.6	-370.8	-3,497.4	-350.1	-403.1	...	...
China	12,220.6	202.4	2,069.0	141.8	928.8	358.5	...
India	1,497.7	64.3	206.7	5.3	414.1	-0.2	1,424.7
Brazil	265.6	1.1	20.3	7.7	21.4	0.0	475.7
South Africa	354.5	5.9	58.0	22.3	49.5	...	1,060.0

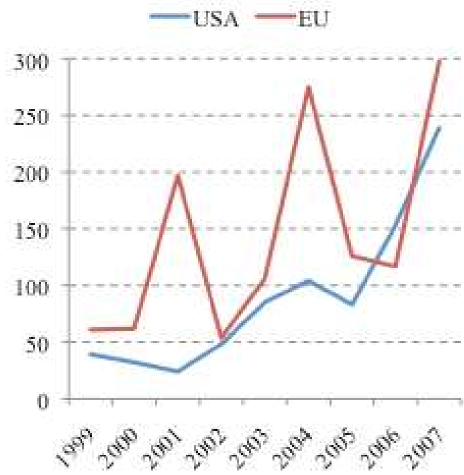
Note: The balance of trade is exports minus imports.
Source: OECD Balance of Payments Statistics

Figure 2.14. *Receipts and payments for royalties and License fees from CIBS countries, 1999-2007.*

a. Payments (imports)



b. Receipts (exports)



Source: OECD Balance of Payments Statistics

Over time, the payments for royalties and license fees by the CIBS countries have increased very rapidly, as Figure 2.14a shows. Perhaps more importantly, the figure also shows that the EU has been able to stimulate demand in the CIBS countries for European scientific or technical knowledge and assistance. This has been largely due to demand from China increasing 20 fold from 1999 to 2006. Figure 2.13b indicates that Europe and the United States have made payments to the CIBS countries for technical knowledge. While the size of the payment is less than a tenth of the receipts from the region, there is an upward trend, indicating that the CIBS countries are also providing some technical knowledge to the Europe and the United States. The sharp changes in the EU trend are mainly due to the size of the trade flow, the nature of the license agreement, and two enlargements of the European Union.

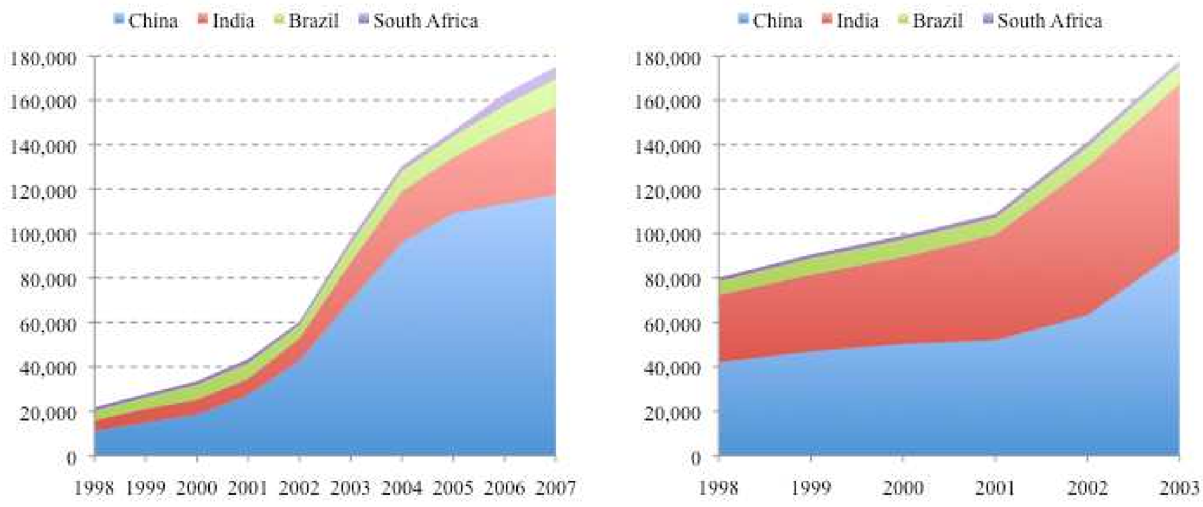
Mobility of students and the labour force. The mobility of students and the labour force refers to the freedom of students to study wherever they want and for workers to practice their occupation wherever opportunities exist. International mobility of tertiary students represents a potential flow of knowledge across national borders. When returning home, they bring back new competencies and possible connections with international research networks. Figure 2.15 illustrates the number of foreign students enrolled in tertiary education in the European Union and the United States. There are no data for the United States after 2003, but the figures indicate that the EU has been able to attract an increasing number in the middle of the 2000s. Evidence suggests that the US attracts relatively more Indian, Chinese and Brazilian students, but there is a stronger connection between Europe and South Africa. Demand for tertiary education in Europe by students in CIBS countries increased about 20 percent per annum from 1999 to 2003. Among the CIBS countries, China registered the highest number of enrolments, the highest growth rate, and the highest mobility ratio. Among European countries, the UK hosted the largest number of CIBS students, in particular from India and China.

Table 2.16 provides information on the stock of foreign labour by nationality. The evidence suggests that United States is the preferred country of residence for foreign workers from the CIBS countries, especially from China and India, which sum to over 2 million workers. South

Africa is the exception, as the number South Africans working in the United Kingdom was higher than those working in the United States. This is mainly due to colonial ties, membership in the British Commonwealth, and a preferential visa system that includes heritage visas, two-year work visas, etc. Table 2.17 provides information on the level of tertiary education of immigrants from the European Union, United States and CIBS countries in five European countries and the United States. ISCED 5 is the first stage of tertiary education, and ISCED 6 is the second stage of tertiary education, which leads to an advanced research qualification. The table indicates that the level of education of immigrants from the CIBS countries is fairly high, most often above the average level of education of a European immigrant, but below the average immigrant from the United States. The one exception is Italy, which appears to attract immigrants with a relatively low level of education. The number of immigrants with advanced research qualifications is relatively small, but it appears that Sweden and the United States attracts more of them than the other countries in the table and that the percentage of Chinese that migrate tend to be highly educated.

Figure 2.15. *Foreign students enrolled in tertiary education in the EU-27 and USA by country of citizenship*

a. EU-27 *b. USA*



Source: UNESCO and Eurostat

Table 2.16. *Stock of foreign labour by nationality, 2007 (thousands)*

	Denmark	*Germany*	*Italy*	*Norway*	*Sweden*	*UK*	*USA*
Denmark	...	13.0	2.2	10.5	38.4	...	26.8
Estonia	0.4	...	0.7	0.8	2.8	...	...
Germany	8.3	...	40.2	10.5	24.7	47.0	570.8
Italy	2.0	390.0	...	0.9	5.1	49.0	220.9
Norway	7.5	6.0	0.9	...	35.6	...	13.1
Sweden	6.6	12.0	9.8	18.3	...	15.0	34.6
UK	8.1	68.0	26.4	6.9	15.7	...	413.3
USA	...	52.0	15.0	3.4	8.3	58.0	...
China	3.4	31.0	156.5	2.9	7.7	32.0	975.4
India	1.9	...	37.9	3.4	14.4	159.0	1,111.4
Brazil	...	...	37.8	1.1	2.0	...	253.5
South Africa	...	...	...	0.3	...	68.0	62.8

Note: Data for Sweden are the stock of foreign-born population. Data for Denmark and the United States are the stock of foreign-born labour by country of birth. These figures tend to be higher as some workers take on the nationality of the place they are working.
Source: OECD International Migration database

Table 2.17. *Education level of immigrants by country of birth and country of residence (percentage of population at least 15 years of age.)*

Residence / Birth	China	India	Brazil	South Africa	EU	USA
ISCED 5						
Denmark	32.1	23.0	31.3	34.0	19.9	45.8
Italy	4.9	9.8	12.7	15.7	6.9	20.0
Norway	31.6	34.5	23.0	48.7	23.0	42.7
Sweden	37.6	25.4	31.3	41.7	22.0	49.4
United Kingdom	47.1	33.3	55.3	46.9	20.5	60.3
United States	39.4	64.2	31.8	52.6	32.1	26.7
ISCED 6						
Denmark	2.3	0.3	0.2	0.4	0.2	1.1
Italy	0.9	1.6	2.7	3.1	1.3	6.4
Norway	2.8	1.1	…	0.5	0.4	2.6
Sweden	16.2	2.6	3.2	7.0	0.8	6.6
United States	5.6	4.9	1.6	3.7	2.5	0.7

Note: Based on 2000 census data. Data for United Kingdom ISCED5 include ISCED6 immigrants.
Source: OECD Database on Migration

2.6 Technological collaboration and global innovation networks

Technological collaboration between firms and organizations is essential for the creation, transfer and absorption of new knowledge as it reduces the risk and complexity involved in the innovation process by spreading it among several partners with agreed complementary aims. Collaboration between academia (universities and research institutes), enterprises and government can be very important for facilitating an idea basic research to applied research and then on to experimental development. Technological collaboration also represents the formation of global innovation networks in which individual enterprises and organizations operate, and may include agreements within an enterprise group, up-stream suppliers, downstream customers, competitors, the government and universities and other research institutes. It often entails the development and acquisition of new capabilities, as each agreement involves a shared commitment of resources and knowledge (Penrose, 1959) and it is closely related to Lundvall's (1992) idea of 'learning by interacting'. Often the form of ownership and the location of a partner in the network can also have important consequences.

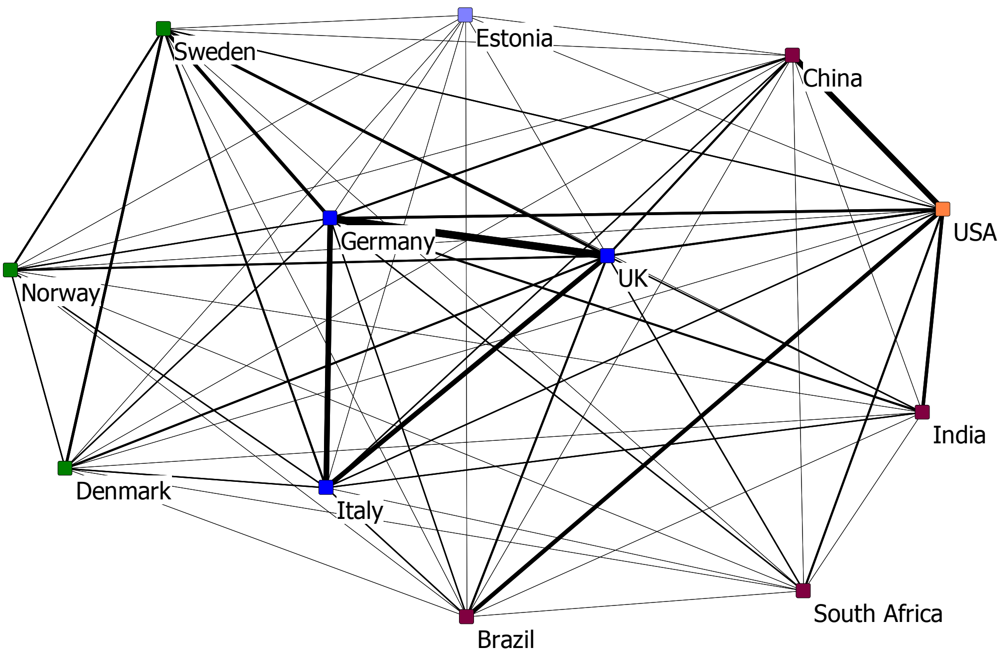
There are many different ways to measure the scale and scope of global innovation networks, especially between Europe, the United States and the CIBS countries. Innovation networks almost always involve some form of collaborative agreements, whether formal or informal, between different actors in the innovation process. Innovation networks can be domestic and play an important role of the diffusion of technology through the national innovation system, but the networks can extent far beyond the national borders. The best way to observe these networks is to use different measures of international research collaboration. Three indicators are considered in this section: (1) co-publications (bibliometrics); (2) co-patenting (patent applications); and (3) collaborative innovative activity between different actors outside the national innovation system. The first measure can be considered as an innovation input as it measures the creation of new knowledge ad the academic level, the second measure is an innovation output that the intellectual property rights assigned to certain knowledge, and the third one captures collaboration in the innovation process itself.

Co-publications. One way to measure research collaboration and the possible global innovation networks is to study the patterns of co-publication between different authors and units across national boarders. Using co-authorship analysis, it is possible to explore the patterns of research collaboration between researchers within the 7 European countries analyzed in this chapter as well as with the CIBS countries and the United States. International co-authorship has increased considerably over the past decade, making it interesting to compare differences between the end of the 1990s and 2000s.

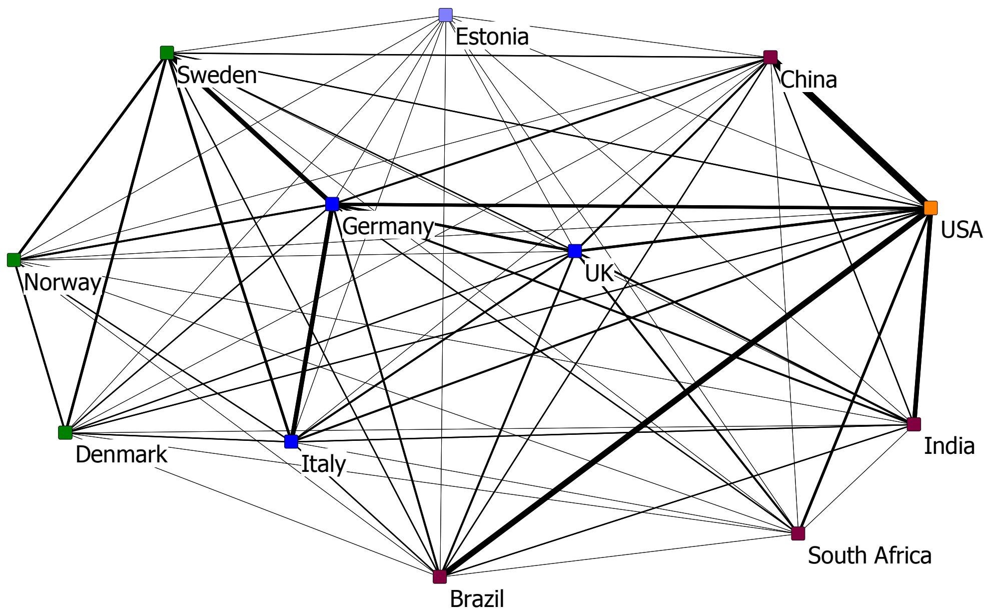
The bibliometric analysis was done using the ISI Web of Knowledge online search facility. This allowed searching for publications from journals with authors from within a specific country and identifying those co-authored publications that had at least two authors from at least two of the 7 European countries, the United States and the CIBS countries and only peer reviewed journals and reviews in the scientific disciplines were included in the search. Data were collected over two three-year periods, 1997 to 1999 and 2007 to 2009, and they count individual authors irrespective of the number of co-authors. Finally, the data collected is based on the number of authors and not the number of publications.

Figure 2.16. *Visualization of the research network between selected European countries, the United States and the CIBS countries*

a. 1997-1999



b. 2007 – 2009



Note: Data for the United Kingdom is England only,
which represents about 85 percent of the total number of authors.
Source: ISI Web of Knowledge

Figure 2.16 shows that in the late 1999s, the three larger European countries, Germany, Italy and the United Kingdom, collaborate more with each other than with any other country. Similarly the Scandinavian countries also tended to collaborate with each other, but Sweden has strong collaborative links with the three larger European countries. The United States has strong collaborative links with China, India and Brazil. There was some noticeable research collaboration between Europe and the CIBS countries, but linkages between the CIBS countries themselves are relatively weak.

Ten years later there appears to be a weakening of the network between the 3 larger countries of Europe, particularly with the United Kingdom, and a strengthening of the network between the United States and the CIBS countries. Not much change was detected between Europe and the CIBS countries. Sweden remains an important player and is well connected within Europe. Germany and the United Kingdom appeared as important collaborators for American researchers in both periods.

Co-patenting. A second indicator of global innovation networks is international cooperation on research as measured by patents involving inventors from a different country of residence. Patents statistics are often used to map the national innovation system, including the intensity of technological collaboration and diffusion. They also reflect the intellectual property rights assigned to certain knowledge, and provide a link between innovation, inventions and the global marketplace. Patent applications often include more than one inventor, and that these inventors do not live in the same country. International collaboration of this kind can take place within a multinational corporation, with research facilities in several countries, or through a collaborative agreement between at least two enterprises or research organizations (and universities). In either case, the indicator would capture international flows of knowledge moving within global innovation network.

Applying for a patent makes an invention public, but at the same time gives it protection. A count of patents is one measure of a country's inventive activity and also shows its capacity to exploit knowledge and translate it into potential economic gains. They also provide an important way to measure global research networks that led to the creation of new technical knowledge and innovation. Patent applications filed under the Patent Co-operation Treaty (PCT) provide the best measures of global research networks. The PCT procedure makes it possible to seek patent rights in a large number of countries by filing a single international application a national patent office or the World Intellectual Property Organization (WIPO). To get protection, applicants must still file within 12 months at the national patent offices where patent protection is desired. The first date of filing of a patent application, anywhere in the world, is called the priority date and is considered as the closest to the invention date.

Table 2.18 describes the evolution of international patent applications with foreign co-inventors filed under the PCT. This table shows that the share of patents with foreign co-inventors is rather

Table 2.18. *Patent applications with foreign co-inventor(s) filed under the PCT, 2000-2007*

	2000	2001	2002	2003	2004	2005	2006	2007
World								
Patent apps	102,500	104,491	108,371	117,085	130,017	141,441	150,899	149,908

Percent of patents with foreign co-inventor(s)								
Total	7.30	7.48	7.48	7.37	7.33	7.37	7.35	7.14
EU-27	5.48	5.58	5.46	5.27	5.29	5.22	5.19	5.10
United States	4.06	4.14	4.05	4.10	4.02	4.00	3.96	3.66
CIBS countries	0.35	0.41	0.50	0.63	0.63	0.72	0.79	0.80
EU-27								
Total Patents	38,952	40,306	40,629	42,014	45,242	47,918	50,803	50,981
Percent of patents with foreign co-inventor(s)								
Total	10.09	10.12	10.21	10.29	10.88	11.00	10.90	10.48
United States	6.50	6.50	6.28	6.38	6.51	6.35	6.24	5.68
CIBS countries	0.37	0.38	0.49	0.57	0.58	0.67	0.83	0.79

Note: Patent counts are based on the priority date, the residence of the inventors and fractional counts.
Source: OECD patent database

Table 2.19. *Patent applications with foreign co-inventor(s) filed under the PCT, 2007*

	Denmark	Estonia	Germany	Italy	Norway	Sweden	UK	USA	China	India	Brazil	S. Africa
Patent apps	1,429	52	19,523	3,375	706	3,463	6,961	50,668	6,762	1,388	563	388
Percent of patents with foreign co-inventor(s)												
Total	19.45	26.92	16.53	14.28	22.52	18.86	23.36	10.82	10.40	25.22	18.83	11.86
Denmark	...	1.92	0.18	0.18	1.13	1.76	0.47	0.13	0.15	0.22	0.53	0.52
Estonia	0.07	...	...	...	...	0.12	0.07	...	...	...	...	...
Germany	2.45	...	...	2.90	1.70	2.51	2.76	1.61	1.52	2.16	2.49	3.61
Italy	0.42	...	0.50	...	0.42	0.69	0.50	0.31	0.13	0.07	0.53	...
Norway	0.56	...	0.06	0.09	...	0.92	0.56	0.07	0.04	...	...	0.26
Sweden	4.27	7.69	0.45	0.71	4.53	...	0.82	0.35	0.40	0.43	1.24	...
UK	2.31	9.62	0.98	1.04	5.52	1.65	...	1.54	0.34	2.09	1.78	2.06
USA	4.76	...	4.19	4.59	5.24	5.11	11.19	...	6.09	15.27	7.28	3.61
China	0.70	...	0.53	0.27	0.42	0.78	0.33	0.81	...	0.43	0.18	...
India	0.21	...	0.15	0.03	...	0.17	0.42	0.42	0.09	...	1.07	...
Brazil	0.21	...	0.07	0.09	...	0.20	0.14	0.08	0.01	0.43	...	...
S. Africa	0.14	...	0.07	...	0.14	...	0.11	0.03	...	...	...	...

Note: Patent counts are based on the priority date, the residence of the inventors and fractional counts.
Source: OECD patent database

stable over time, despite the number of patent applications increasing by about 50 percent over the seven-year period. There appears to be a slight decline in the world share of patents with foreign co-inventors in the EU and United States, but share of patents with foreign co-inventors more than doubled in the CIBS countries during the period. Table 2.19 describes the structure of foreign co-inventions in 2007. This table shows that the United States, and to a lesser extent Germany, are important collaboration partners for all countries. Also the Scandinavian countries tend to collaborate together and with Estonia. China has the lowest percentage of foreign co-inventions, but it filed more patents under the PCT than any other country except the United States, Germany and the United Kingdom. It also appears that the

CIBS countries prefer to be in networks with the advanced European countries rather than with each other. These tables confirm that global knowledge networks are pervasive.

Innovation collaboration. Collaboration in innovative activities provides another indicator of global innovation networks. This indicator reflects collaborative activities involved in the introduction of a new good or service, a new method of production, or a new form of organization. It only partly echoes research and patenting activity. The indicator is based on questions from the Community Innovation Survey, which provides information about the geographic location of the partner and several different types of collaboration, including collaboration with other enterprises in the same enterprise group; upstream suppliers; downstream customers; competitors; consultants; R&D laboratories; (7) universities; and public or non-profit research institutes. It is not, however, possible to combine these data with the location of the partner without using the original firm level data.

Table 2.20 shows the share of innovative enterprises engaged in cooperation from 2004 and 2006 based on two Eurostat Innovation surveys and Eurostat aggregations. There appears to be a slight decline in the share of collaborative activity from 2004 to 2006, but this is likely to be statistically insignificant. The table suggests that enterprises in Scandinavia and Estonia are collaborating more often than other countries. In all instances, collaboration is more likely if the partner is national or in Europe. What appears to be more important is that enterprises collaborating in international networks are much more likely to collaborate locally. This conclusion suggests that collaborative arrangements with foreign partners are important for the transfer of foreign knowledge to the local economy regardless of the local or foreign ownership of the firms (Knell and Srholec, 2008). Innovation surveys were also carried out in Brazil, China and South Africa, but they are not directly comparable with the Eurostat surveys. The chapters on these countries in this report will discuss these issues further.

The idea that GINs can evolve in a self-organizing way, often containing individual collaborative agreements suggests that innovation cooperation will be prevalent in small and medium sized enterprises. Figure 2.17 shows the relative difference between small, medium and large enterprises from the mid 2000s. The figure indicates that the larger the enterprise, the more likely it will be involved in some kind of collaborative network. This is not surprising because large multinational enterprises are often involved in *many* different innovative activities and the innovation survey only asks whether the enterprise in engaged in *any* activity.

Table 2.20: *Percentage share of Innovative enterprises engaged in cooperation, 2004 and 2006*

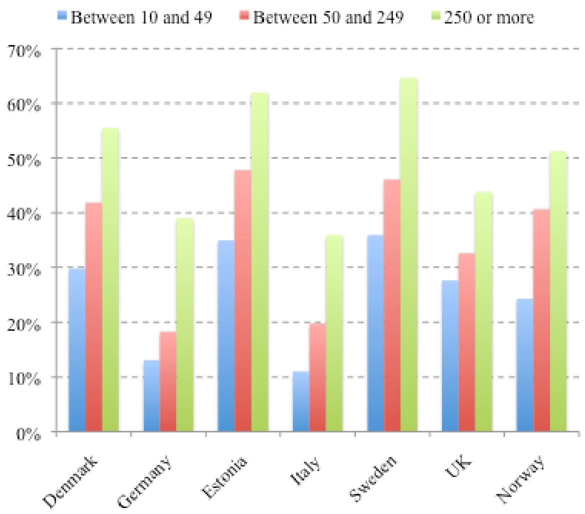
	All types of co-operation	*National*	*Other Europe*	*United States and other countries*
2006				
Denmark	34.2	25.7	16.9	13.7
Germany	16.7	...	...	...
Estonia	39.5	30.5	26.7	6.1
Italy	13.5	...	...	...
Sweden	40.0	37.0	23.6	9.4
United Kingdom	29.5	...	...	...
Norway	29.6	23.0	11.8	8.0

2004				
Denmark	42.8	38.7	27.8	9.6
Germany	16.0	15.3	4.7	2.6
Estonia	34.8	28.8	24.5	9.6
Italy	13.0	12.4	2.5	1.1
Sweden	42.8	40.2	21.2	6.9
United Kingdom	30.6	...	...	...
Norway	33.2	30.9	19.3	9.7

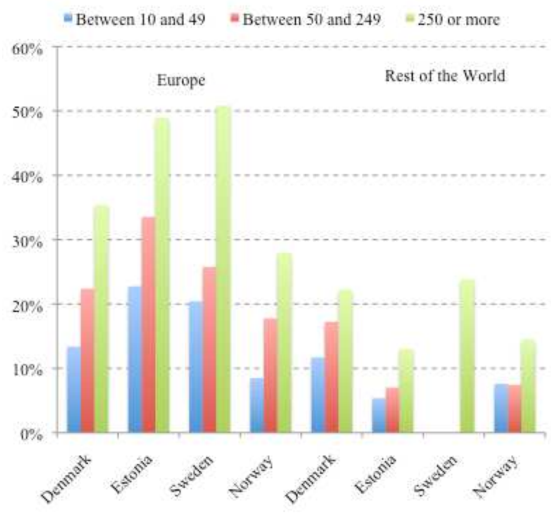
Source: Eurostat Community Innovation Survey, 2004 and 2006.

Figure 2.17. Percentage share of Innovative enterprises engaged in cooperation by size of enterprise, 2006

a. All innovation cooperation activity



b. Global innovation cooperation activity



2.7 From global production networks to global innovation networks

This chapter considered the possibility that global production networks are transforming into global innovation networks from a comparative empirical point of view. It did this by investigating the national innovation systems of seven European countries, the CIBS countries and the United States and how they relate to global innovation networks. One thing that becomes clear in the analysis is that China and India appear to be moving on a path of economic growth that will close the productivity gap over time. Gaining access to already existing global innovation networks and new network formation help to explain why this is happening. It is less clear that Brazil and South Africa are on the same path of economic growth, but there is evidence that they are getting increasingly involved in the global networks.

There is considerable diversity across the different countries included in the analysis. Different institutional arrangements crate different varieties of capitalism and national innovation systems. Both Hall and Soskice (2001) and Amable (2003) consider the United Kingdom to be a liberal market economy more similar to the United States than to Germany, which is generally seen to be more in the direction of a coordinated market economy more typically found in Scandinavia. All three Scandinavian economies are small, open and dynamic will similar institutional arrangements, but the economic structure of these economies appear quite different. Denmark has a large number of entrepreneurially based small and medium-sized enterprises; Sweden relies heavily on large knowledge based enterprises; and Norway is a resource-based economy that relies heavily on knowledge based services. Germany is a large economy, with many knowledge-based enterprises. All of these countries rely heavily on collaborative learning, often jointly with each other, to remain on the technology frontier.

The CIBS countries show both similarities and differences in their interactions with the EU. They show both similarities and differences in their interactions with the EU. There are similarities in that all four countries are relatively large in geographic size and population, the income and wage levels in these countries are significantly behind the European average, income distribution is very unequal, and all four countries are important regional players. But they also have distinct political systems, with varying degrees of direct and indirect state involvement in the economy. All four countries are far from the technology frontier, but there are examples where these countries have become global players in certain industries, such as ICT manufacturing in China, ICT services in India and biofuels in Brazil. China and South Africa appear different because of their scepticism toward foreign ownership as a means toward accessing better technology, whereas Brazil and India more heavily rely on multinational activity and embodied technology transfer.

Despite sharing many common features, the individual CIBS countries are fairly heterogeneous, posing quite different challenges and calling for specific policy responses on the side of their partners, especially the EU. The Chinese economy is driven mainly by exports of labour-intensive manufacturing exports and domestic investment in fixed capital. India is a highly diverse economy, ranging from simple handicraft to modern production techniques, and has become a major supplier of labour-intensive manufacturing exports and knowledge intensive services. Brazil is essentially a domestic-oriented service-driven economy, but it has become a major supplier of natural resource-based manufacturers in recent years. South Africa is a bit smaller than the other three, also focuses on agro-based and resource-intensive manufacturers. The resource orientation of Norway appears to resemble the economic structures of the latter two economies, but the technological capabilities are very different.

Many enterprises located in the CIBS countries are part of a global production network (GPN), often producing various components for high technology product in a vertical value chain that require relatively low skills. Yet, there is evidence that some enterprises in these countries are actively involved in global innovation networks (GINs), which coincides with the general rise in competencies observed in these countries. But there is some network misalignment taking place. Both India and South Africa are experiencing critical skills shortages with the education infrastructure unable to provide the needed skills. In Brazil a private sector education is developing to meet that need. China has the necessary infrastructure, but struggles to develop a local innovation capacity beyond imitation and market seeking activities.

The European Union as a whole appears to actively participate in a multitude of global innovation networks and that the relatively higher productivity levels enjoyed in the United States may be misleading. Both the United States and Europe are in many of the same networks and interact on many different levels. And all of the countries contain large centrally controlled multinational enterprises that attempt to direct and control the innovation network that they are part of. They also contain smaller enterprises and research groups that interact in global innovation networks that are more self-organizing and moving with the needs of the members that are part of it. This dual nature of innovation networks fits well with the stories told in the subsequent chapters on the United Kingdom, Germany and the Scandinavian countries about different layers within each national innovation system.

Estonia appears as an interesting case of catching-up in the analysis. They are a new Member State in the European Union, but they are also an economy that is has a relatively low productivity level, but high productivity growth. It is also a small country that has many cultural and linguistic ties to the Nordic countries, and as the study shows, also quite well integrated into Nordic collaborative networks. Having immediate neighbours on the technology frontier, with considerable foreign direct investment, encouraged Estonia to be more open in the way it developed its capabilities and accessed global markets.

One possible shortcoming of this chapter is that the data do not capture the recent financial crisis and subsequent global recession. While there is evidence that cross-border mergers and acquisitions have subsided in the last two years, it is not clear whether the global recession has had a major impact on the long-term investment strategies of global enterprises. Interviews done for a Rindicate study (Shapira, 2009) of R&D international funding flows indicates that they have had little immediate impact on their long-term research strategy. There is some evidence from the European Restructuring Monitor that some consolidation started to take place in late 2008 and early 2009 that resulted in what might be considered reverse off shoring. But it may just be a temporary trend.

This chapter provided a comparative analysis of the countries that are discussed in more detail in the subsequent chapters. It also told a story about how the individual innovation systems are tied together through an evolving global network of innovators. It however has little to offer in terms of policy prescriptions. Nevertheless, two sets of policy issues become apparent. First, the emerging economies need to develop the institutional arrangements that facilitate the creation of global knowledge networks and integrate them into their innovation systems. Enterprises need to build and improve their capabilities, and integrate them into global innovation processes. Second, there is the need to consider carefully what specific policies can encourage enterprises in the European Union to create and benefit from an increased number of global innovation networks with these rapidly moving emerging developing economies.

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Chapter 3: Germany

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3.1 Introduction

When Otto Keck published the first analysis on the innovation system in Germany in 1993, he began with the following words: “Germany is a special case, for several reasons” (1993: 115). This remark refers first to the political history of two Germanys after World War II and, second to the extraordinary exports performance of the West German economy for more than 40 years. We would claim that Keck was and still is right but that additional reasons exist to characterize the German National Innovation System (NIS) as “special”. One additional reason is that the German NIS is much more driven by the private sector than in most other countries. Additionally, the organization of the private sector is unique and this organizational structure is embedded into a special form of “national” capitalism.

The specificity of the business sector is that in addition to a number of big companies that stand for the bulk of formal Research and Development (R&D) spending and patenting, the economy is very much driven by a large number of small and medium sized enterprises, often family based, the so-called Mittelstand. According to different studies, this Mittelstand is highly innovative, even if this innovativeness is not always reflected in formal R&D spending tagged as such, and many of the innovative improvements of products and processes will not lead to filing a patent. And, following the varieties of capitalism debate (Hall/Soskice 2001), Germany’s way of organizing capitalism is till date based on coordinated governance, against claims that Germany is on its way to a neo-liberal capitalism of an Anglo-Saxon form.

Mittelstand and coordinated governance still form the broader backbone of the German innovation system. In the following section, the role of political governance of the German innovation system is outlined. In section 3 we will first give an overview of the actors in the German NIS, highlighting the specific role of the business sector. Section 4 briefly discusses the interrelationships between the various actor groups in the German innovation system, while section 5 sketches the learning system, stressing the specificities in the field of vocational training and higher education. Section 6 outlines domestic and international networks and some of the policies geared towards strengthening international linkage building in order to enhance innovativeness. In this section, the topic of global innovation networks comes to the fore. A concluding chapter draws on the still prevalent “German paradox” (Canzler et al. 2010) – strong research but weak commercialization – and future prospects of Germany as a node in global innovation networks.

2. Institutional arrangements of the German national innovation system

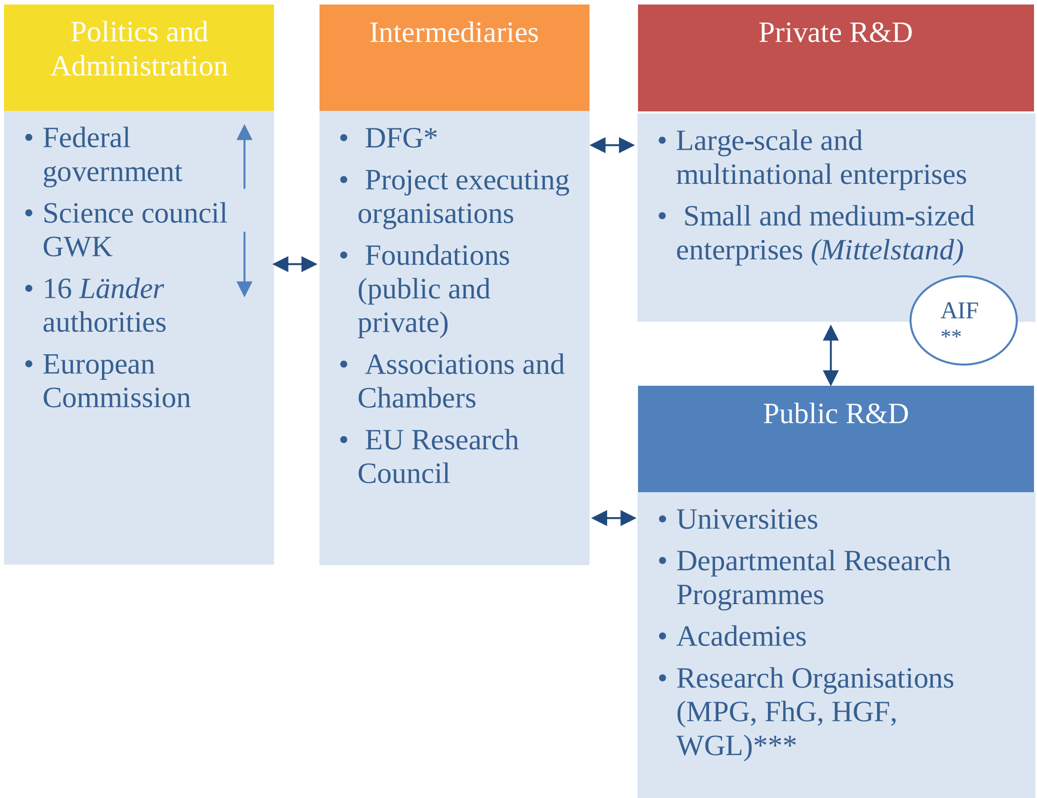
Science, technology and innovation (STI) policy in Germany is highly complex as the responsibilities are distributed between several Federal Ministries. Contrary to what is the case in other countries, the ministries have a high degree of autonomy, as neither the foreign office nor the chancellor's office has a dominant role within the government. Coordination and cooperation among the ministries and thus, policy coherence, in common or closely related issues in the context of STI is sometimes done, but far from self-evident, as it mainly depends on the will and initiative of the individual actors within the government and no clear incentives exist to invest resources in time-consuming interaction with neighboring ministries.

The two major actors in the federal government engaging in STI are the Federal Ministry of Economy and Technology (BMWI) and the Federal Ministry of Education and Research (BMBF) but there are additional players involved, such as the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) or the Environmental Ministry (BMU). The division between the responsibilities of the Ministries is not always clear-cut. For instance, in energy research, BMBF is in charge of basic research and BMWI in applied research leading to a great deal of blurry interfaces; BMELV is responsible for bioenergy related research and BMU for some environment related aspects of future energy production. The German Federal Ministry of Economic Cooperation and Development (BMZ) is responsible for international agricultural research, e.g. for the funding of the Consultative Group of International Agrarian Research (CGIAR).

Additionally, STI policy is subject to a multilevel governance, with 16 Länder executing own programs and projects, complementing (but rarely coordinated with) the measures financed and executed by the Federal government.[1] Since a recent reform of the German federal system the 16 Länder have a rather exclusive responsibility for the traditional universities and the universities of applied sciences and thus, for an important element of the NIS. Additionally, they have a significant array of own instruments of business and STI promotion. These embrace not only mechanisms to promote German economy domestically, but also international networking. Thus, for instance, some of the larger Länder sustain partnerships with provinces in other countries or maintain offices for business contacts abroad. There are no institutionalized mechanisms to coordinate programs and instruments of the federal government with those of the Länder, conducing to a complex and little transparent multilevel governance of the German innovation system. Figure 3.1 summarizes the main elements of the governance structure of the German NIS.

[1] *In some areas, e.g. promoting start-ups of technology oriented companies; even administrative units below the level of the Länder (districts, municipalities) implement their own measures.*

Figure 3.1: *Governance structure of the German NIS*



* DFG = German Research Foundation (Deutsche Forschungsgemeinschaft)

** AIF = German Federation of Industrial Research Associations (Arbeitsgemeinschaft Industrieller Forschungsvereinigungen)

*** MPG = Max Planck Society; FhG = Fraunhofer Society; HGF= Helmholtz Society; WGL = Leibnitz Association

Source: VDI/VDE-IT

Network and linkage building: an important issuen for German STI policy. Beyond channelling public resources to the promotion of pre-competitive research and in fields where spefically large externalities can be expected, linkage and network building among the actors of the innovation system has been an important concern of policy makers for a long time and has been targeted with dedicated instruments of innovation policies.

Only four examples shall exemplarily be sketched, as they correspond to different points in time and different applications of instruments. Overall, they share the objective to strengthen linkages between different elements of the German innovation system:

- The Joint Industrial Research program (*Industrielle Gemeinschaftsforschung*) was set up in 1954 and was designed to specifically addressing the STI needs of the Mittelstand. Companies that share a common challenge related to their products and processes can form an association and as such contract with a university or research organization to carry out a dedicated R&D project. The economic approach behind the program is to help overcoming market failures specifically relevant for smaller business units. The

R&D shall happen at a pre-competitive stage. Between 2005 and 2009 an extensive evaluation was carried out, coming to a positive appraisal of its effects on the innovativeness of the German Mittelstand (AIF …).

- In the mid-1990s there was increasing awareness that Germany was lacking behind other industrialized countries in the field of commercial biotechnology. A program was set-up called Bio-Regio-contest. Three times DM 50 million (€ 25.6 million) were earmarked for public support to the development of regions especially competitive in commercial biotechnology. A “region” was defined as a geographically close network of at least one actor from the publicly funded research system, a private company and a public administration unit. The funding was organized as a two-step competition, where regions first had to submit a concept paper on how they would use public funding for the development of biotech. Out of approximately 80 applications the 16 most promising were selected, and competed in the second phase. Anecdotal evidence indicates that the concept was successful; not least in inducing regional and cross-sectoral cooperation networks (see Dohse 2000).
- Most recently, in 2009, the decision was made to merge two leading organizations in Germany’s IS, the Technical University of Karlsruhe with the Forschungszentrum Karlsruhe, the largest organization within the Helmholtz-Society (HGF) (see chapter 3). The idea behind this merger is to further enhance cooperation and use synergies.

While the cooperation between “peers” (business to business, academia to academia) has made important progress, bringing the different communities together has been a major headache for Germany’s STI policy makers and administration. Since the 1970’s technology transfer centers and offices for innovation advice were mushrooming across Germany, very often located within or close to universities. Together with business incubators and other intermediaries around 1000 such organizations were counted in the mid-1990’s (Reinhard and Schmalholz, 1996). Evaluations of these programs indicated a rather poor performance in relation to effectively fostering cooperation between public STI organizations and business, especially when Mittelstand companies were to be induced to cooperate with public research organization. A number of reasons have been put forward to explain this:

- Fears of core business knowledge leaking out to competitors;
- Different aims of actors in the private sector (patenting) and in public research organizations (publishing);
- Different time horizons between private (finding concrete solutions as soon as possible) and public research (profound research to prepare high level publications;
- The “not invented here” syndrome, meaning a skeptical view towards externally generated knowledge and technologies by senior managers and/or owners;
- Different “languages” spoken by representatives from academia and business.

The failure of many offices in technology transfer can largely be explained by the fact, that the approach corresponds to a linear view of the innovation process, or the “knowledge cascade” where new knowledge generated ‘upstream’ (basic research) is taken up by organizations of applied research, which further elaborate on the knowledge and develop products and processes that might be interesting for business R&D and marketing. IS research has long shown that this linear model does not really reflect the reality of today’s innovation processes, which are largely characterized by feedback loops and interactive processes.

One conclusion drawn from the rather negative experiences in technology transfer is that a promising approach is to bring knowledge and technology producers and knowledge user together at an early stage. Close user-producer interaction differs largely from technology transfer, converting the process mainly in a co-development of innovations.

A rather successful approach to match users and producers of advanced technological knowledge is the "Steinbeis-Foundation" mainly active in the south - western *Land* of Baden-Württemberg. It reflects specificities of the German IS both on the business side (Mittelstand) and within the institutional meso-level (Universities of Applied Science, see below). The Steinbeis Foundation has a very lean organization, with a small headquarters in Stuttgart and several hundreds of small transfer offices, mainly hosted by Universities of Applied Science and administrated by a "moonlighter", a Professor who runs the Centre as a secondary work. These professors are the reference persons for the business sector. As they teach and conduct research on very "hands-on" subjects, some of the mentioned hurdles for private-public interaction in STI (different languages, different time horizons) are less severe or even inexistent. Moreover, having interaction between business and research partner at an early stage, the process resembles more a contract research with close personal interaction, opposed to efforts to "sell" ready-made innovations to the business community, as the traditional technology transfer model advocates.

3. The main actors and their activities

Germany is the largest economy in Europe and the third largest exporter on world markets. International competitiveness is high, mainly in sectors which have developed in earlier Kondratieff cycles: engineering and machine tool industry, chemical industry, and automobile industry. The OECD classified these sectors as "Medium-High-Technology". Their strong competitiveness is based on regular, incremental innovations. The largely unbroken success of this strategy of permanent improvement of given products and processes may in part explain a fact that is often pointed out as a weakness of the German NIS: Its lack of preparedness when it comes to convert groundbreaking inventions into commercially successful innovation. In fact, in several cases (such as the mp3 data compressing format) technologies invented in Germany were not developed into marketable products at domestic markets but abroad.

Figure 3.1: *R&D Intensity, Germany 1991-2008*

Source: OECD MSTI database, 2009.

R&D Spending: Figure 3.1 shows that after losing ground compared to many other OECD countries, regarding Gross Expenditure on R&D (GERD) in relation to the GDP since the late 1980s, this trend was stopped and reversed at the end of the 1990s. The expansion of the budgets for R&D conduced to Germany left a rather poor mid-table rank within the OECD during the mid-1990s to an acceptable place within the upper range among OECD countries in 2008. However, with a GERD/GDP ratio of 2.5 percent in 2007 the gap to the international best performers is still large (Sweden: 3.6 percent, Finland: 3.5 percent, Japan: 3.6 percent) (BMBF 2010: 450). The German R&D system differs from other countries in three respects (see Table 3.1): 1) The private sector provides the overwhelming and still increasing part of R&D spending; 2) University R&D is relatively low, and 3) Research labs play a relatively high role in the R&D system.

Contribution of the private sector in Germany’s innovation system: When analyzing the available data in order to get an understanding of the drivers and linkages within the German innovation system, it is important to have a closer look, especially when it comes to the contribution of the business sector. In the German case, the realization of innovation system research, that innovation should not be equalized with formal R&D is of special relevance.

Table 3.1: *Contribution of different sectors to GERD/GDP ratio, 1995-2007 (in percent GDP)*

Year	1995	2000	2005	2007
Private sector	1.45	1.73	1.72	1.78
Universities	0.40	0.39	0.41	0.41
Public laboratories	0.34	0.33	0.35	0.35
Total	2.19	2.45	2.48	2.54

Source: BMBF 2010

Looking at an assessment of the distribution of R&D expenditure of the different sectors, it can be stated, that in Germany the private sector is by far the largest contributor, with € 43 billion or 69.7 percent of all R&D spending in 2007.[2] In this regard, Germany compared well with many of the global leaders in technology and innovation, such as Finland (68.2 percent), Sweden (64 percent) or USA (66.2 percent) and is only topped by Japan (77.7 percent). [3]

Going more into detail regarding the private sector’s contribution to Germany’s R&D efforts, it becomes clear that the bulk of the investment comes from a rather small number of German Multinational Enterprises: In 2008 R&D spending by the Daimler automotive company reached € 4.4 billion, corresponding ten times the basic funding of all 60 centers of the Fraunhofer Society together (see below). In 2009 Siemens invested € 3.9 billion in R&D, BMW € 2.9 billion, Bayer € 2.8 billion and BASF €1.4 billion. Volkswagen (VW) leads the European list regarding the spending in R&D, worldwide only surpassed by Toyota and Microsoft. In 2008, VW invested € 5.9 billion in R&D.

[2] The following facts are taken from the recently published Bundesbericht Forschung und Innovation (Report of the German government on research and innovation).

[3] These data refer to the financing of R&D; the data for R&D execution differ only in some details.

However, it can be claimed that the German innovation system is not exclusively characterized by global players, but also by a strong sector of small and medium sized innovative firms. In this respect, the R&D data do not adequately reflect the drivers of innovation in Germany. Here, the role of smaller business units is frequently overlooked, as their innovative activities are often not executed in separate R&D departments or based on budget lines especially earmarked for R&D. In many cases, product and process innovation are often the outcome of continuous incremental improvements, induced by senior staff members or the owner himself in the case of Mittelstand companies. Improvements are often triggered by mere observation or by feedback from the companies' clients (for the importance of user-producer interaction for the generation of innovations, see Lundvall 1985).

The claim that smaller business units play a special role in the German innovation system is not fully supported by the recent ZEW (Centre for European Economic Research) innovation report, which states that the ratio of innovators largely depends on the size of the firm. The report, however, makes a difference between research intensive industries where 75 percent of even very small firms (less than 50 employees) do innovation while the ratio is at only 50 percent in the sector of knowledge intensive services, 48 percent in other industries, and just over 30 percent in other services (Rammer et al. 2010, 11ff).

Research-intensive industries include the chemical and pharmaceutical industry, electrical industry, mechanical engineering and the automotive industry. These are the sectors of strong competitive advantage in German exports. In contrast to large firms (more than 500 employees), which have seen a steady increase in their innovation budgets from a total of € 35 billion in 1995 to € 95 billion in 2008, small firms did not substantially increase their innovation expenditures in this period (€ 25 bill. and € 33 billion respectively). This difference holds true for the current period (2009/10) as well (Rammer et al. 2010, 13).

Among the large firms, referred to in the ZEW report figures, many belong to the so-called German Mittelstand, which has been claimed to be so strong in the German economy. The Mittelstand is mainly distinguished from other segments of the business sector, by ownership and governance structures, and not mainly by the company's size. The Mittelstand is mostly composed of family owned firms, which can have thousands of employees and a significant number of locations all over the world. Many of these Mittelstand enterprises have been characterized as hidden champions because they are world market leader or global second bests in a variety of different market niches. Venohr and Meyer (2007) see approximately 1.300 world market leaders in the segment of firms with a turnover of more than € 50 million each in Germany and estimates further 1,000 firms as micro world market leaders.

As a result, driving agents in the private sector of the German innovation system are both large multinational companies and small and medium sized champions belonging to the Mittelstand. Interestingly, these firms often initiate regional networks as platform for technological information and establish contacts to nearby and remote domestic universities. It remains to be seen, however, whether the hidden champions are as active as the multinationals in establishing global innovation networks. In a second step, the contribution of the private sector to R&D and innovation shall be analyzed on the sectoral level. Various studies prove that the German innovation system is largely based on sectors of so-called advanced technologies or medium-high-technology goods and services. Table 3.3 shows the percentage of companies with innovation activities for the year 2008.

Table. 3.2. *Innovation activities in the German economy, 2008*

Ranking	Sector	percent of firms
1.	Chemical/pharmaceutical industry	89
2.	Information technologies	86
3.	Electrical industry	84
4.	Automotive industry	79
5.	Engineering industry	78

Source: Rammer et al. 2010, 15

Table 3.3: *R&D expenditures (total and internal) of different sectors of the German economy*

	R&D expenditures	
Sector	total (in billion €)	internal (in billion € and percent)
Chemical industry	8.3	6.7 (80.7%)
Of which Pharmaceutical	4.7	3.4 (72.3%)
Mechanical engineering	5.5	5.0 (90.1%)
Electrical industries	10.8	8.7 (80.6%)
Automotives industry	20.0	15.1 (75.5%)
Business services	4.7	4.1 (87.2%)

Source: Rammer et al. 2010, 15

While the sectoral R&D intensities have not changed dramatically in recent decades, the observed growth of R&D in the private sector is mostly due to changes in its sectoral composition. Nevertheless, the German innovation system still draws its strength from a few advanced technology sectors, among them the automobile sector (Polt, 2010).

Table 3.3 indicates that across the industrial sectors, the by far highest contribution to the overall R&D spending can be still classified as intramural. The pharmaceutical and the automotive industry are the only sectors where around one quarter of R&D spending is actually executed by external actors (extramural R&D). It could be claimed that these sectors are prone to establish global innovation networks first.

Public funding: As table 3.1 shows, contrary to the OECD average, universities did not see an increase of their shares in public R&D funding while public R&D labs still play a considerable role in the German innovation system. R&D funding at Germany's Universities is largely channeled through the research council, the *German Research Foundation* (Deutsche Forschungsgemeinschaft, DFG). In organisational terms, the DFG is an association under private law. Its membership consists of German research universities, non-university research institutions, scientific associations and the academies of science and the humanities. The DFG receives the large majority of its funds from the states and the Federal Government, which are represented in all Grants Committees. At the same time, the voting system and procedural regulations guarantee science-driven decisions.

Four clusters of R&D labs can be distinguished which are largely or completely financed by the central government and/or by the governments of the *Länder*.[4] Each of these four

[4] Germany is a federal state with 16 provinces or Länder. The main competencies of the Länder lies in education were the central government has very little influence.

groupings has specific historical origins and different missions related to covering specific R&D needs:

The *Max-Planck Society* (MPG) (successor of the Kaiser-Wilhelm Society, founded in 1911 and dissolved after WWII) has 80 Institutes and is mainly engaged in basic research, with only few exceptions in "hard sciences". The Federal Government and the provincial Länder governments of where the respective institute is located jointly finance it. For 2010 € 616 Million were earmarked for the basic funding of MPG.

The *Helmholtz-Society* (HGF) is Germany's largest research organization. It employs approximately 30.000 people in 16 Centers across Germany. The estimated budget for 2010 amounts to about € 3 billion, mainly financed by the Federal Government. Many of the Centers have their origins in R&D in civil usage of nuclear energy, such as: developing new lines of nuclear reactors (Karlsruhe, Jülich) or exploring the possibilities to use nuclear energy for the propulsion of ships (Geesthacht). Others are research labs established around large-scale research infrastructure, such as particle accelerators (Hamburg, Darmstadt). The Helmholtz Centres have gone through significant reforms since the early 1990s. An important turning point was the political decision in 1989, to abstain from the further development of the fast breeding technology and the related recycling of used nuclear elements. This made the nuclear agenda of many Centers obsolete and a diversification process was initiated. In 2001 the HGF was formed and a new, inter-center programming of research programs introduced.

The *Fraunhofer Society* (FhG) is the main organizations of applied research in a large array of technical disciplines. In currently 60 Institutes around 17.000 persons are employed. A combination of basic funding by the state, public project based funding and third party financing (mainly through industry contracts) allow combining autonomous research with a high degree of client orientation, mainly towards companies of the Mittelstand. The FhG Institutes work in a rather independent way. As their fields of expertise overlap to some extent, the Institutes often compete among themselves for market contracts. These internal incentive systems explain to a large extent the very successful growth and development process of the FhG, since the first Institute was established in 1949.

4. National learning systems and technological capabilities

While it is generally acknowledged that education and training are important prerequisites for the growth and development of modern knowledge-based societies, it appears to be difficult to identify a direct causal relationship between the growth of GDP and general indicators of education. Instead, we assume that education and training form a separate sub-system of its own whose impact on the national innovation system is rather complex. More important, however, is the fact that many indicators used for international comparisons are contested as not being able to seize the different systemic characteristics of national education and training (see on various aspects Schmoch et al. 2006). Nevertheless, it seems necessary to arrive at some kind of benchmarking, both for analytical and political reasons. To better understand the particularities of the German education system and its possible contribution to the National Innovation System, we will refer to some very recent publications, which attempt to develop new indicators from a critique of those given from the OECD, for example.

The general picture of the German education and training system can be described as following: At basic educational level, pupils are educated together until including the fourth grade. Afterwards they are split-up into three levels; mainly corresponding to their performance in grades one to four. Pupils successfully finishing the basic level (*Hauptschule*, after nine years) are entitled to enter the vocational training systems (see below). Finishing the intermediate level (*Realschule*, after 11 years of schooling) with success allows pupils to either opt for a professional training in “white collar” jobs (e.g. in the public administration) or to continue to achieve the qualification to enter a University of Applied Science (after twelve years, see be-low) or a University (after thirteen years). Pupils successfully finishing education in the third level of education (Grammar School, after twelve years) are entitled to apply for tertiary education at university.

There is a general understanding that the German education system has over the last decades lost much of its former strength compared to other OECD nations (Leszczensky et al., 2010, 1). The OECD Program for International Students Assessment (PISA) recently pointed out some severe deficits among German pupils in core competencies like reading and writing and in core subjects like mathematics. Another matter of concern is the underperformance of the German educational system in assuring social mobility through education, reflected in a very low percentage of pupils with a working class or migration background achieving access to tertiary education.

Additionally, indicators related to the ratio of highly qualified people or to public expenditures into education clearly show below-average scoring. The percentage of graduates in higher education among the cohort of 25 to 34 years old people was only 16 percent in Germany in 2007 compared to 21 percent in the OECD average and 31 percent in the Netherlands or the US (Leszczensky et al., 2010, 82). Public expenditure for education was 4.3 percent of GDP in 2001 for Germany while the OECD average was at 4.8 percent. An even more serious matter of concern, however, is the fact that public spending has been reduced in the course of time when other countries have increased it (Dohmen 2006). A closer look on the German education and training system reveals many differences in various elements of the education system.

Specificities of the German education and training system. Germany has a strong dual vocational education and training system (VET) (Uhly, et al., 2006), only applied by some smaller neighboring countries, i.e. Austria, Denmark and Switzer-land. This dual VET system combines private in-company training with public schooling and final examinations by the semipublic Chambers of Industry and Commerce. Approximately 60 percent of a year’s school leavers look for a further qualification in vocational education, both dual and fully school-based (Leszczensky, 2010, 73). In the long run Uhly et al, (2006, 211) see a rather constant high level of 60 percent of the apprenticeship participation rate (per age group of young people) against a considerable volatility over the years. Almost constantly since 1992 half a million young people per year successfully passed the examinations. VET qualifies approximately two thirds of the 18 to 21 years old people. In total, the dual VET system forms a strong base of the German education system. It has been modernized at various occasions, increasingly since 1996. Between 1996 and 2004, 230 training regulations have been renewed and 59 new occupations created (Uhly, et al., 2006, 218).

Although the dual vocational education and training system is considered responsible for a long lasting “comparatively low level of youth unemployment” in Germany (Uhly et al., 2006, 207), it has been regularly regarded "in crisis". There is a continuing debate about the system's adaptability to major changes in the economic system concerning demography, technology and innovation and the sectoral composition of the German economy. Modernization of training, particularly in technical professions, seems to be at stake. Over the recent decades, the entrance requirements to the dual vocational system have shifted to an intermediate general school certificate. Although only a minor part of young people have a higher education entrance qualification, these higher-level entrance qualifications seem to suppress lower entrance qualifications.

It is generally argued that the high commitment of the German education system to vocational education hampers a further increase in the participation of young people to higher education. Since 1990, rather constantly 23 percent of a year's population has a degree in higher education (Leszczensky et al. 2010, 16), which is quite low compared to other countries (Dohmen 2006). Hence, a recent report on the educational system of Germany comes to the conclusion that Germany has lost much of its competence in education and holds a rather weak position among the OECD nations. As Dohmen (2006, 249) puts it: "the picture is even more dramatic when comparing the qualification levels of the 25 to 34 years olds in 1995 and 2002".

Taking into account the strong VET system and methodological issues of indicator building, the recent assessments points to a weakness in Germany's sector of higher education. Leszczensky et al. (2010) argue that the current indicators on formal qualification of the labor force do not correctly apply to the characteristics of the modern knowledge society. They suggest another cross-formal qualification levels indicator on competence and competence building. They differentiate between knowledge creating, knowledge acquiring and knowledge using occupations across sectors of production, primary services and secondary services provision. In 2007, almost 30 percent of all employees are estimated to be engaged in knowledge creating and acquiring occupations, with strong focus on the secondary services sector (64 percent).

While Germany is far below average regarding the ratio of higher education graduates in employment in Europe, it is just average regarding the ratio of knowledge intensive occupations. Needless to say that graduates from higher education are mostly concentrated in the secondary services sector whereas the knowledge intensive intermediate level qualifications (level of master and technician) are concentrated in the production sector – mirroring the strong dual VET system. This is particularly true for the very large sector of the automotive industries where the share of knowledge-intensive activities is rather average but the number of knowledge intensive jobs rather large (Thiemann, 2009, 60).

In higher education, the so-called MINT (Mathematics, Information Science, Natural Science, and Technology) disciplines are considered to be a good base for the technological development of the German economy. Although with a decreasing share, Germany still reveals strength in the qualification of engineers and graduates from sciences (based on OECD data, see Leszczensky et al. 2010, app.1). There were different processes of decrease and increase in the different MINT disciplines, whereby the information sciences are the early winners and engineering disciplines are the possible losers. Finally, there is an increasing gap between low qualified workforce and high-qualified workforce as most further education is provided for highly qualified people.

In the long run, the German education and training system faces a series of challenges, essentially important in the field of the MINT, which are mainly related to a changing demography, leading to increasing problems in filling places at Universities, especially at postgraduate and Ph.D. levels. To some extent this might be absorbed by a “feminization” of studies. Already today, a gradual shift in women’s preferences in training can be observed, making inroads into classically “male” domains. In the long run, an important source of human resources might be found in the migrant population living in Germany that maintains comparatively high birth rates. However, this would require significantly improving the performance of the educational system, as in Germany, the percentage of people with migration background reaching college or university level training is extremely low. Migration of qualified people could also be a way out. However, also in this case, policy would be required to shape attractive conditions for highly skilled immigrants. The rather poor achievements of the German “Green Card” initiative from 2000 to 2004, targeting specifically IT experts, can be taken as a proof that Germany is facing tough competition from countries like USA and UK when it comes to attracting high-potential employees from countries like India.

Finally, one specificity of the German education and training system should be mentioned, as some scholars relate the rather strong innovative performance of the German Mittelstand at least in parts to its existence. Since the late 1960s the concept of the University of Applied Science (Fachhochschulen, FH) was developed and gradually implemented.

The FHs are institutes of tertiary education that differ from the classical University by offering shorter education (usually three instead of four years) with a more “hands-on” approach as compared to the more academic training. This corresponds specifically to the knowledge needs of small and medium companies and allows them to contract highly trained personnel at a lower cost than relying on graduates from classical universities. Additionally, the R&D carried out at the FHs is very much in line with the requirements of smaller companies. In many cases, research done in order to graduate from a FH includes a concrete “problem-solving” R&D project carried out by the student in a company and in direct collaboration with its senior technical staff. FHs are not entitled to award Ph.D. titles.

It is not for nothing that the probably most successful example of technology transfer in Germany, the Steinbeis Foundation (see section 3) capitalizes on these assets of the FHs, by linking companies to the specific expertise of these training and research centers. It is not by chance, either, that the Steinbeis Foundation has its stronghold in the Southwestern state of Baden-Württemberg, known as a region with a very high density of Mittelstand companies.

5. Knowledge flows and networks in the national system of innovation

Whitley (2002) points out that the social organization of the German economy is based on collaboration and networking among stakeholders from the private sector and other organizations. One can expect a multiplicity of network formation aiming at or fostering knowledge transfer and enhancing the firm’s innovation performance. Most innovation networks, however, are vertically organized ego-networks. Most innovating firms receive incentives for innovation or collaborate for innovation with their suppliers and, to a lesser degree, with their customers.

Networking has two connotations in this context: one between different types of actors such as from the public, the academic and the private sectors (in the sense of triple helix, innovation system etc.); the other on the spatiality which may be linked to the kind of network. We start to look at different geographies of networks, first on networks embedded in regional and national environments, and, second, on the likelihood of extending innovation networks across borders.

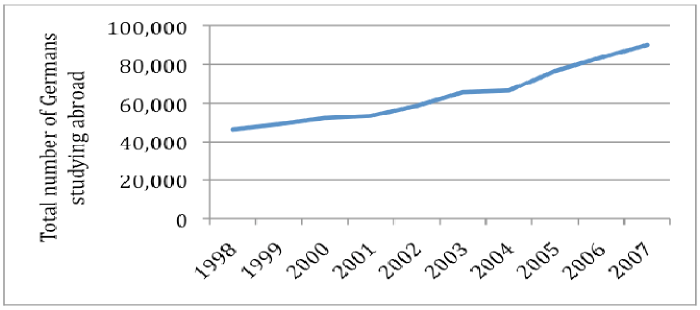
The cross-sectoral in-business networking is supplemented by a host of broader and often regional networks encompassing public authorities, academic institutions and private firms. Research following the industrial district approach has revealed close but rather unplanned contacts among a diversity of local actors for innovation in some recent technology districts in Germany such as biotechnology in Munich (Sternberg/Tamacy 1999) or opto-electronics in Jena (Hassink / Wood 1998). Federal research and economic policies and the *Länder*’s regional policies have implemented regional networking policy tools being convinced that regional networking enhances global competitiveness of firms. To stimulate structural (sectoral) change of the German economy, the Federal Ministry of Research and Education launched a first regional contest in the early 1990s, the BioRegio contest. It was aimed at fostering biotechnology in certain regions, which promised to be or might soon become globally competitive in the sector (Dohse 2000). There were four winning regions, i.e. the bio-regions Munich, Heidelberg, Cologne and Jena. The policy instrument obviously was so promising that the Ministry later implemented additional contests, among them the InnoRegio programme to stimulate regional innovativeness in Eastern Germany (Eickelpasch/Fritsch 2005) (see section 3).

In fact, this and other contests initiated local networking for innovation in new and old sectors and new and old industrialized regions. Taking the Frankfurt Rhine Main Area as an example, networks on biotechnology (Frankfurt Biotech Alliance) or new materials (Materials Valley) have been launched by combined efforts from the private sector, academia and state policy (see Schamp 2003). Where the automotive industry is concentrated, similar efforts have resulted in a number of regional automotive networks (for innovation), as for example in Bavaria, Baden-Württemberg, Hessen, North Rhine-Westphalia and Saxony (Blöcker et al. 2009). Additionally, sectoral associations have created their own innovation networks such as the FAST in the automotive industry. These networks have been initiated to strengthen the absorptive capacity of regional firms and plants for global knowledge.

All these activities come close to what Cooke and Morgan (1998) have called “the associational economy” where local authorities, para-public organizations such as Chambers of Industry and Commerce (where membership of the larger local companies is obligatory), sometimes local universities (often Technical Universities or Universities of Applied Science) and private companies create topical networks on certain technologies. It is, however, crucial to note that most networking takes place in a pre-competition phase in the innovation process, when experimenting with or gaining new ideas across sectors and technologies matters more than designing new products (as particularly emphasized for the automotive industry, see Blöcker et al. 2009).

Networking abroad in science, technology and innovation: The extent and the forms of international knowledge flows seem to largely differ between the public and the private sector, or between the pre-competitive and the competitive field of innovation activities. The absolute number of Germans studying abroad has risen from 33 000 in 1990, 42 000 in 1995, 52 000 in 2000 to more than 90 000 in 2007 (last available data, see figure 3.2).

Figure 3.2: *Germans studying abroad (1998-2007)*



Source: DAAD 2010b

Also the number of foreign students in Germany has quickly been rising, from 150 000 to nearly 250 000, between 1997 and 2009 (DAAD 2010b). Still, internationalization of German higher education is largely a Europeanization, with most Germans studying in geographically close countries, such as the Netherlands, UK or Austria and also more than 50% of the foreign students in Germany coming from a European country. At least on the recipient side, things are gradually changing, with the number and percentage of students of Asian origin obviously increasing (from 47 000 to 60 000, between 2003 and 2006) (BMBF 2008). The geographical pattern is similar with regard to the number of university cooperation. In 2008 (no time series available) around 20 000 international university cooperations were reported by 280 German universities, partnering with 4100 foreign universities in 141 countries. From these cooperation partners, 32.5 percent were located in Europe; however, Asian countries were nearly as often mentioned (15.9 percent) as the traditional research partner North America (16.0 percent)[5] (DAAD 2010a).

These data indicate that there is considerable dynamism in the internationalization of the primarily publicly funded and pre-competitive parts of the German NIS. The geographical reach of this process has a clear focus on Europe; however, there are indications that a real globalization of STI networks has a least begun. This is by far not so clear with regard to the cooperation networks of the private sector and competitiveness related issues.

The emergence of regional networks for innovation in Germany – as mentioned above - can be partly interpreted as a response to the perception of increasing threats from R&D going international in the 1990s (Belitz et al. 2006, 47). R&D expenditures and employment abroad by German multinationals had nearly doubled between 1995 and 2001 (Belitz 2010: 3). Total R&D expenditures abroad rose from 4.9 billion € in 1995 to 11.4 billion € in 2005 and 9.4 billion in 2007.

Table 3.4: *R&D expenditures by German companies doing R&D abroad, in 2007*

Selected sectors	Global R&D in bill. €	R&D abroad in bill. €	Percentage of R&D abroad

[5] An interesting detail of the available data for 2008 is that the Technical Universities are much more active in international cooperation than the traditional universities and the Universities of Applied Sciences.

Chemical industry	8.4	3.7	44.1
Pharmaceutical industry	3.0	2.1	69.2
Electrical and instruments industries	7.4	1.2	20.2
Automotive industry	18.1	3.0	15.6

Source: Belitz 2010, 9

Table 3.4 shows that the principal sectors investing in R&D abroad are the chemical industries, the electrical and instruments industries and the automotive industries. The most internationalized R&D system is in the pharmaceutical industry and the chemical industries in total, while the electrical and instruments industries and the automotive industries do R&D abroad to a lesser degree (Belitz 2010: 9). At home, the automotive industry reveals the highest shares among all manufacturing sectors with 35 to 38 percent in domestic R&D expenditures.

Total R&D expenditures abroad decreased to € 8.8 billion in 2007, according to the data from SV Wissenschaftsstatistik. The trend to more R&D abroad turned into reverse. German multinationals have increased their R&D abroad in the late 1990s and early 2000s mainly by mergers and acquisitions (Belitz 2010, 5). This came to a halt in recent years, and it seems that the financial crisis has reduced the likelihood of R&D investment abroad even more. It seems as if increasing R&D in other countries is perceived to a lesser degree as a threat for the competitiveness of German industry, but possibly also less as an opportunity. Internationalization of R&D has particularly been reduced in recent time in Germany's leading industrial sector, the automotive industry (Belitz 2010: 6).

When discussing internationalization of innovative activities, a sectoral approach is crucial. In the most internationalized sector of the German economy, the pharmaceutical industry, large global enterprises seek to collaborate with or take over small firms in global – mostly US – Centers of excellence (e.g. Zeller 2004). In the automotive industry, which counts for 52 percent of international R&D expenditures of the German manufacturing sector (in 2007) and where large Original Equipment Manufacturers (OEMs) exert hierarchical power on their value chains, the bulk of innovative activities has shifted from these leaders to their suppliers. As can be seen from the distribution of R&D net product, 31 percent of it occurred with the OEMs, whereas suppliers created 61 percent and service firms 8 percent in 2005. This is expected to further shift towards suppliers and engineering services in the near future (Blöcker et al. 2009, 17).

Looking at the geographical distribution, Western Europe and the US come by far first. What is more important is the kind of innovative activities involved. Firms are very aware of safe-guarding their competitive advantages. According to many studies, most firms simply do adaptation processes to local markets at their foreign R&D locations (see Blöcker et al. 2009). Case studies reveal that large OEMs and probably first tier suppliers as well act globally in the pre-competitive phase of innovation activities when long term trends and visions, both in technologies and consumer's behavior, matter the most. Nevertheless, they still concentrate highly complex product development at home. A case in point is BMW, with its large Munich R&D centre for model development (8,000 employees) but further offices in the largest markets, i.e. in Silicon valley (concerning technology, design and emissions), Tokyo (technology), Beijing (technology) and Singapore (design) (Richter/Harting 2007). A similar spatial organization seems to be at stake in the extra-mural R&D system of research labs and, in particular, universities. While OEMs have close linkages to German universities (technical universities, Universities for Applied Sciences) for proprietary innovative activities, they are simultaneously members in global networks between technical universities in pre-competitive activities (Legler et al. 2009).

Similar to the halt of German R&D going abroad is the development of R&D expenditures and personnel of foreign firms in Germany. The increase of foreign R&D in Germany during the 1990s has reached a seemingly stable level of 25 to 27 percent in the recent decade. The share of foreign R&D in domestic R&D is highest in the pharmaceutical industry (47 percent), followed by the chemical industry in total (37 percent), the electrical and instruments industry (27 percent) and the automotive industry (24 percent). Generally speaking, the sectoral distribution of foreign R&D in Germany is similar to that of German R&D going abroad.

Table 3.5: *Share of foreign firms in R&D in Germany, 1993 to 2007*

	1993	1997	2001	2005	2007
Expenditures	15.5	17.8	25.2	27.2	27.3
Personnel	16.7	18.1	27.3	27.4	26.1

Source: Belitz 2010, 11

Internationalization of R&D is geographically extremely concentrated. Germany ranks second as a major home and host country of R&D by multinationals after the US (Belitz 2010, 11). Inward and outward R&D relations are rather similar in their geography. While multinationals from European countries, mainly from Germany’s neighbors The Netherlands, Switzerland and France, have the lion’s share of foreign R&D personnel in Germany (56 percent), and the US ranking second (38percent). German multinationals do R&D mainly in European countries (60 percent as measured by patents, see Belitz 2010, Belitz et al. 2009), among them Switzerland (14 percent), France (13 percent) and Austria (10 percent). R&D in the US accounts for 31 percent. Technological specialization of domestic R&D by German multinationals is similar to their foreign R&D (Belitz et al. 2009, 13). Foreign R&D is mainly orientated on local adaptation, however. As a consequence, neither Japan nor any of the recent emerging economies are integrated in the global R&D system of Germany.

In a long-term comparison of the early 1990s and the early 2000s, Belitz et al. (2009) show an increasing geographical concentration of R&D abroad on Western Europe, as measured by patents statistics. The percentage of German foreign activities in R&D in Western Europe was 47.3 percent in 1990-3 and 60.1 percent in 2002-5. In the engineering and automotive industry this figure was even at 70.4 percent in 2002-5, according to Belitz et al. (2009). In the same course of time, the US lost importance (from 44 percent in 1990-3 to 30.7 percent in 2002-5) as did Japan (from 5percent to 2.3 percent, respectively), while emerging East Asian countries slightly increased their importance, mostly Korea and China (from 1 percent in 1990-3 to 2.4 percent in 2002-5).

Political support to the internationalization of the German innovation system: As in the case of domestic STI policies, the political initiatives to foster the internationalization of German companies are highly complex and embedded in multi-level governance. In most cases, it is difficult to distinguish between measures to promote domestic companies’ access to foreign markets from a focused approach to strengthen access to partners for STI cooperation.

On the national level, three instruments represent Germany’s approach to promote exports and international cooperation of domestic companies:

- The Foreign Chambers of Industry and Commerce (Außenhandelskammern, AHK) are representations of German companies abroad, but also have members from the host country with special interests in Germany. Currently 120 AHK exist and provide an array of services to the member companies, mainly information services, contact brokerage and the organization of special events, such as trade fairs. The AHK receive a core financing from the German Federal Ministry of Economy and Technology (BMWi) but also earn a reasonable share of their budgets by selling services.
- Germany Trade and Invest – *Gesellschaft für Außenwirtschaft und Standortmarketing* (before 1 January 2009 „Bundesagentur für Außenwirtschaft” (BFAI)) also provides market relevant information to German companies interested in „going abroad“, and promotes Germany as location to do business, to invest and to cooperate in STI.
- The “third” pillar of external economic promotion is formed by the embassies, which, among a rather wide array of tasks, represent the interests of the German private sector, especially in countries where no AHK exists.

While the three mentioned programs provide generic support to companies seeking markets and/or partners abroad, there have been several attempts to specifically target cooperation in R&D between German and foreign companies:

- During the 1990s and early 2000s, special contact persons to promote technological cooperation were appointed to work with AHKs in countries where significant technological capabilities are located (Technology Area Managers).
- The German Federation of Industrial Research Associations (AiF), an organization that basically promotes domestic research and technology cooperation for several years maintained offices abroad in order to widen the scope of its work.

Both programs have meanwhile been phased out, mainly due to an unfavorable relation of costs to benefits.

The existing programs are funded by the German Federal Ministry of Economics and Technology (BMWi). BMWi shares responsibility for research and technology with other Ministries, first of all the Federal Ministry for Education and Research (BMBF). In order to induce international network building, BMBF followed the “two-plus-two” approach for a couple of years. This approach implies that special lines of funding were provided for bilateral R&D cooperation projects, if at both sides at least one private company and one research organization are involved.

In 2008, the German cabinet approved a concept, drafted by the BMBF and negotiated with other Ministries, under the heading of “Strengthening Germany's role in the global knowledge society - Strategy of the Federal Government for the Internationalization of Science and Research”. This internationalization strategy lists four objectives for international STI cooperation, as there are:

1. Strengthening research cooperation with global leaders: German researchers shall cooperate closer with the most innovative researchers and with internationally leading

research groups in future. At the same time, Germany shall become first choice for the best researchers and students from all over the world.

2. International exploitation of innovation potentials: German companies must secure a good place in the world's leading and newly emerging high-tech markets and win the world's most creative R&D centers as partners. In this way, Germany's attractiveness as an environment for innovation, particularly for R&D-intensive companies shall be increased.
3. Intensifying the cooperation with developing countries in education, research and development on a long-term basis: Scientific and technological cooperation and development cooperation will be better coordinated in future.
4. Assuming international responsibility and mastering global challenges: Germany will use its research and innovation potential to contribute to the solution of global challenges in the areas of climate, resources, health, security and migration. In this context, Germany will be able to substantiate not only its science policy goals but also its foreign policy and development objectives.

6. Summary and concluding remarks regarding main characteristics, performance and internationalization of the German NIS

Among the specificities of the German NIS, when compared to other countries with a long tradition of industrialization and technological development (such as France or UK) is the fact that it is very much driven by the private sector. Large multinational companies are financing the bulk of R&D spending in Germany. Smaller units, in many cases family owned Mittelstand companies, drive innovation by continuous improvement of products and processes, often not related to formal R&D spending. Around these innovation-based companies, a complex system of supporting industries and policies on different governance levels has emerged.

Assessing the overall performance of the German NIS is far from easy. Taking overall competitiveness of the national economy as the lead indicator, it may be said that the German NIS is doing rather, but not exceptionally, well. In the most recent (2009-2010) Global Competitiveness Report, developed by the World Economic Forum, Germany ranks among the “top ten”, concretely on rank seven, behind Switzerland, USA and three of the Nordic countries (Sweden, Finland, Denmark) but ahead of other countries, known for their recently good economic performance, such as Taiwan, Norway or Korea.

Germany’s NIS is very strong when it comes to scientific output and inventions, but rather weak in translating these inventions into commercially successful innovations (the “German paradox”). Germany remains strong in medium-high-technology industries, where competitive advantages have been built up since the 19th century, such as machinery, automotive or chemical industries; but relatively weak when it comes to make significant inroads into new high-tech sectors, such as biotechnology or the information and communication technologies.

According to Canzler et al. (2010) this not completely satisfactory situation can be attributed to a deficit in the overall setting of the German NIS. It largely follows the rather outdated “waterfall model” of the innovation process where knowledge created “upstream” (basic research) is taken up “downstream” by organizations of applied research and, finally, by R&D

departments of the business sectors. This setting does not reflect new insights of innovation research that innovation processes in the current knowledge society are largely characterized by interactive processes between the actors of the system and by important feedback loops between the different “steps” of the innovation chain. Some recent reforms reflect these insights, trying to establish significant “bridges” between various steps of the innovation chain, e.g. the efforts to bring public and private STI actors closer together through competitions (e.g. the Bio-Regio contest) or the formation of the “Karlsruhe Institute of Technology”, merging a very important research lab with a traditional technologically oriented university. Concrete outcomes of these reforms, however, have still to be seen.

Regarding the internalization of the German NIS, there are mainly indications that the publicly funded parts of the system (primarily the technical and traditional universities) are building up networks with peers from other countries, in first place clearly within Europe, but increasingly also beyond, e.g. with partners in Asia. Evidence with regard to the private sector and, thus, with the competitive parts of the NIS does not allow similar conclusions. Companies still seem to be rather reluctant to relocate innovation related functions to other countries; and when this happens, internationalization is mostly restricted to the neighbouring countries. The same holds true for the opposite direction, i.e. incoming innovation activities. These mainly reflect the strong sectors of the domestic economy, and they link Germany mainly to some European neighbours and the US. In conclusion, German companies thus prefer to have strong control on innovation through short distances.

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Chapter 4: The United Kingdom

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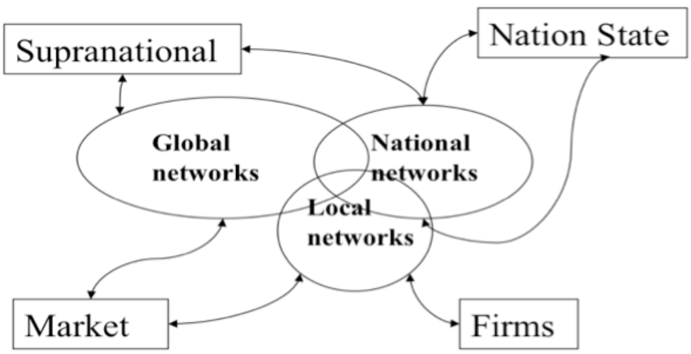
4.1. Introduction

In this chapter, we propose a framework for studying the UK's national learning system as the consequence of various strengths and weaknesses, built upon two approaches that we have been favouring in recent years, namely a dynamic interactive capabilities perspective on each individual agent in the system, together with a network alignment perspective on the system more broadly in terms of how well or poorly integrated in to the various levels of the system more generally. This includes the international/global system of innovation in which it is more widely embedded. Figure 4.1 tries in a quite simple manner to capture this embeddedness, using the categories of agents which will later be related to modes of governance ['markets', hierarchies both corporate (= 'firms') and political (= 'governments'), and networks'] by bringing the latter together with spatial differences, the figure thus incorporates what we understand to be the basic point underlying modern discussions of 'multi-level governance'.

The dynamic and interactive capabilities framework rests on an approach to capabilities pioneered by Nobel Laureate Amartya Sen for the case that we refer to as consumer capabilities. In addition there are two further actors in the national or any economic system, namely the producers and the upstream suppliers, of technology, as well as more traditional supply chain providers. These have two distinctive aspects: firstly a schematic division between agents and actors, whereby agents can come from many industries or sets of firms, universities, research laboratories, governments, etc, though in a national system actors however can be of only three kinds i.e. as suppliers, producers and consumers/ users; although each agent can be playing all three roles at the same time. Such multitasking readily takes place at the individual as well as the corporate level; take for instance the writers of this chapter - we do not and would not claim to be anything special, but at the time of producing the chapter, in accord with the best exercise of our abilities we are also engaged as suppliers (to the audiences of, say, policy-makers or academics of logically ordered information, aimed at

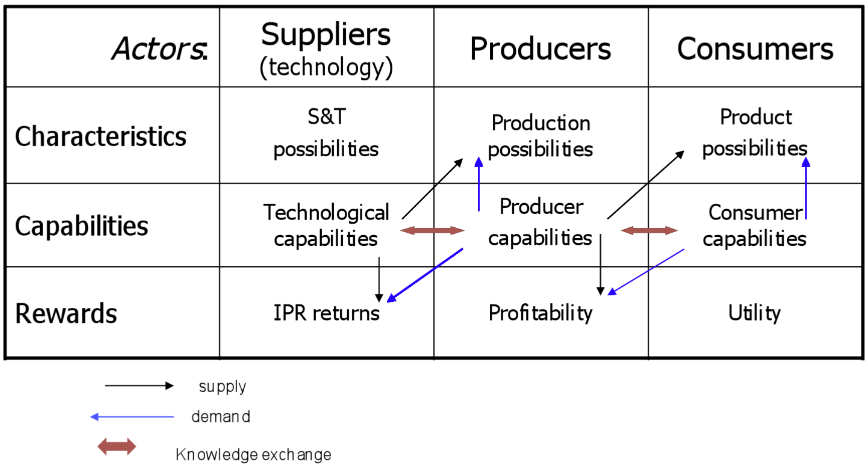
Figure 3.1: *Agents in a supranational setting*



enhancing the chapter, in accord with the best exercise of our abilities we are also engaged as suppliers (to the audiences of, say, policy-makers or academics of logically ordered information, aimed at enhancing their competencies in the field, and furthermore as consumers/users, of all those hardware and software products that ease our production and distribution tasks each day, as well as the accumulated wisdom of all our predecessors as exemplified by our citations to their books, papers, reports, etc.

The outcomes are then represented in Sen's (1985) view of capabilities vectors as shown by the rows of the table in Figure 4.2 where the roles of the actors are given in the separate columns. Any act of learning or innovation involves some market-related forces of supply and/or demand operating at the characteristics level as well as capabilities, which dictate their strengths. Equally the rewards of innovation can be captured by the supply and demand factors determining such rewards in the final row of the table. There are also the very important flows of knowledge between the actors at the level of capabilities shown by the two-headed arrows, and which reflect the true examples of interactivity – beyond the immediate reach of market mechanisms or IPR protection. Note also that capabilities serve (vertically) as the lynchpin between the characteristics (of product, process, and technology),[6] and the rewards that their sales generate for the relevant supplier and demander. Thus there is no one-to-one relationship between technological characteristics (say) and the deployment of such technologies in actual production; instead, what firms confront is a key transformative function played by the capabilities it musters, for which a significant element is the speed with which they are able to turn 'mere competencies'[7] into capabilities, so crucial for absorptive capacity, etc.

Figure 3.2: *A scheme of interactive capabilities*



[6] 'Technology' here stands for anything that the supplier happens to supply, which embeds some degree of capability.

[7] This term is not meant to imply any disparagement of the role of competencies (see Tunzelmann, 2009), but is offered in the same spirit that Schumpeter and Marshall discussed 'mere management', etc.

4.2. Agents and outcomes of the UK's national learning system

The data available on S&T performance and funding for the UK from the end of World War II to about the mid-1990s are collected and graphed in von Tunzelmann (2003), and the present summary will just survey and update these figures where necessary.

R&D performance. Figures on R&D expenditures have become the most commonly cited of national indicators pertaining to technological performance. It is widely believed that the UK is stronger at 'upstream' science and technology than at 'downstream' adoption and diffusion, so if anything UK expenditures tend to overstate its relative international performance in technology. Figures of 'R&D intensity', i.e. GERD (Gross Expenditure on R&D) relative to the country's GDP, suggest a rapid build-up to a plateau of around 2.3 percent from the late 1950s to the early 1990s, followed by some decline in those years of the early 90s. These figures suggest the UK as at best holding its level of R&D intensity, though failing to match the longer-term rises experienced in comparable European economies like France and (West) Germany. Over the decade from 1995 to 2004, the average R&D intensity in the UK had fallen to about 1.8 percent, compared with 2.2 percent in France, 2.4 percent in Germany and 2.6 percent in the USA (figures from UK Office of National Statistics database). More positively, the number of researchers per thousand employed (both measured in 'full-time equivalents') reveals a rise of 28 percent between 1990 and 2006; we shall come back to this apparent inconsistency in section 3.1.2 below.

In terms of BERD, i.e. business expenditure on R&D, in the long run there is again basic stability – from the late 60s through to the late 80s BERD sticks at about 1.5 percent of GDP, before declining in the 90s, notwithstanding the (part-) privatization of many government laboratories like the Atomic Energy Authority, which 'artificially' boosted private-sector R&D. Again, the UK did relatively badly compared with its international rivals.

For the case of HERD as a percentage of GDP the story is very different – here a positive performance by the UK not only features but almost dominates the picture. Until the cuts in university funding at the end of the 70s the contribution of UK higher education institutions to the country's R&D was well below that in comparable countries. Responses to the cuts, oriented towards applied objectives in order to secure non-governmental funding, more than doubled the HERD contribution to UK GDP during the 80s. By the mid-80s the UK ratios were in the same ball-park as its rivals, and by the mid-90s there was strong convergence among the major countries. It can reasonably be claimed that the UK was successful in steering its universities into industrially relevant research. As of 2006, R&D performed by higher education (including the research councils) in the UK was half of that performed by the entire business sector (BERD), whereas in 1996 it had been little over one third as much (ONS data).

Thus the pattern observed for the UK is rather different from most industrially advanced countries – instead of a slowdown in government R&D expenditure being more than offset by rising business expenditure, the UK witnessed a slowdown in business R&D expenditure, perhaps even a fall, and a rise in higher education R&D that was offset by a fall in government expenditure in other domains.

R&D funding. These figures on expenditures, reflecting amounts performed by the respective agents, must be clearly differentiated from the sources of funding. In most countries, and the UK is no exception, the government funds considerably more R&D than it performs. For instance, industrial funding was under one-quarter of total R&D in the mid-50s, but industry still did most of the performing (Gummett, 1991). In 1996 private business in the UK funded about 47 percent of total domestic R&D but performed about 75 percent (Diederen et al., 1999). By 2006, the respective proportions were 45 percent and 62 percent (ONS data). In the UK most of this 'subsidy' to industry has reflected military R&D, where the government contracts out a substantial portion of defence-related R&D.

Large changes occurred during the 1980s and early 90s. At the beginning of the 1980s government funded around half of the total R&D performed in the country, but from 1983 this share dropped away (Georghiou, 2001). Industry's share rose from just over 40 percent in 1981 to a maximum about 10 points higher in 1988 A rising share funded by foreign sources, i.e. by increasing reliance on foreign-based multinational companies, and by other national sources (e.g. charities), compensated for Part of the falling government share, especially after 1988. Charities were especially important in funding basic scientific research.

Overall the experiment of cutting UK government spending on R&D in the hope of boosting private R&D can hardly be judged a success. The growth in the UK R&D stock was the slowest of the G6 countries 1972/89 and especially in 1990/4 (Buxton et al., 1998: 172).

Patents. Patent figures are regularly, though sometimes inadvisably, used as a measure of the output of technology. Most scholars are prepared to use them to gauge trends through time, if used with due care.

1) The data for patents in the USA, chosen because it is the largest world market, relative to other advanced countries apart from the US, show UK patenting as declining in most periods from the 1880s onwards (when the published data begin), except for the interwar period (Pavitt, 1980: 38-44). After World War II the UK instead shows only a very slow trend increase in US patents per capita, reaching its peak in the early 1970s.

2) Alternative series are available for patenting at the European Patent Office (EPO) from the early 1980s. For the years for which data are available (1995-2003) the average annual number granted to UK patentees was 112 (per million capita), compared with 127 for France, 149 for the USA, and 266 for Germany. Though this figure rose by 49 percent between 1995 and 2003 for the UK, the percentage increases were somewhat greater for these three comparator countries (Office of National Statistics data). To the extent that patents do provide some indication of technological 'output', the data give little comfort to the view of a strong UK performance.

3) So-called triadic patent data, aggregated over the US, European and Japanese Patent Offices, available for the more recent years, show procyclical variations, like a drop in 1991, albeit with a relatively steady path from 2000 to 2006.

Science – publications and citations. As a guide to the underlying strength of technology, the growth of the science base is an obvious pointer. Using data from the Science Citations Index for 1981/2000, the UK shares of both papers and citations thereto remain at respectably high levels, despite the global spread of science and scientific endeavour.

The numbers of publications when compared to the material covered above appear to indicate a much healthier state of British science than of British technology throughout the periods for which we have reasonable data. A government report in 1997 showed the UK carrying out 5.5 percent of the total world's research effort, producing 8 percent of the world's publications and 9.1 percent of all citations (May, 1997; Diederen et al., 1999). The Office of Science & Technology thus showed a high ‘productivity’ of British science in terms of papers per amount spent on science, although it can be doubted whether like was being compared with like. Even if valid, to many this simply reflected the low amounts spent in the denominator rather than the high outputs achieved in the numerator of the productivity calculation (Georghiou, 2001). The data do at the same time make the government attempts in the 1980s and early 90s to blame universities rather than industry for Britain’s economic woes rather implausible.

By the 1980s research funding had reached a stage which John Ziman captured in the title of the report, Science in a ‘Steady State’ (1987). The report contrasted the sustained growth in science funding of preceding decades with the levelling off of the 1980s, which he considered would continue. At the same time the need for science showed no sign of levelling off, and the costs of undertaking science were also on the rise. How could this situation be squared? Industry and government implored academia to adopt more business-like methods, which were partly pursued; but to critics within academia this was imposing on them the values and methods of a more dubious UK business system.

Hidden innovation. A series of reports emanating from The National Endowment for Science, Technology and the Arts (NESTA, 2006, 2007, 2008) have pointed out that, “Historically, the UK has suffered from poor performance relative to its major competitors on traditional measures of innovation” (NESTA, 2007: 4), for instance R&D per capita, but better once what it calls measures of ‘hidden innovation’ are taken into account. Sector-specific studies suggest the following indicators of such ‘hidden innovation’ (inter alia):

1) “Innovation that is identical or similar to activities that are measured by traditional indicators, but which is excluded from measurement…”;
2) “Innovation without a major scientific and technological basis, such as innovation in organisational forms or business methods…”;
3) “Innovation created from the novel combination of existing technologies and processes…”;
4) “Locally-developed, small-scale innovations that take place ‘under the radar’” (ibid.: 5).

As these reports argue, the over-emphasis on traditional indicators has led to a situation in which, “Consequently, policymakers have responded by incentivising R&D, encouraging businesses to collaborate with universities and substantially increasing public investment in scientific research” (ibid.: 4), rather than promoting these sources flagged by due recognition of ‘hidden innovation’. However the belief that such hidden forms of innovation particularly distinguish the UK remains an article of faith.

Sectoral systems. The literature on sectoral systems of innovation has not yet been able to demarcate clear boundaries for what it embraces by each sector – usually falling back on OECD definitions of ‘industries’, which are an inconsistent mixture of product-based and technology-based categories. Yet the work of Malerba (2005) and colleagues has adduced the main drivers of such ‘systems’, as summarised here under four sub-headings.

1) Opportunity: Most concern has been expressed in this connection as relating to technological opportunities, though as ICTs became general-purpose in nature they lost their sector-specific identities. Market opportunities would seem to be more applicable

to the given context of product-oriented sectors, and here the British situation was varied. There seems to be some agreement in the literature that government ownership and regulation of the National Health Service benefited the growth of the UK pharmaceutical industry through its stability, whereas frequent changes induced by erratic governmental decision-making proved disruptive in some other high-tech markets (like nuclear power). In geographical terms, British producers have been criticised for restricting their exports largely to safe Empire and Commonwealth markets (e.g. Owen, date, for motor vehicles).

2) Appropriability: Here the issues have tended to focus on patenting, or rather the lack of it (as the statistics previously cited demonstrate), by many British companies and other organisations. It is widely believed, for instance, that British success in patenting of pharmaceuticals boosted financial support for that industry. However it is conceivable that British companies were better at developing 'dynamic' modes of appropriability such as lead time, than at 'static' modes such as patenting.

3) Cumulativeness: In this aspect the issues focused on matters of size and concentration. The 1960s and 70s had witnessed a quest for large corporations able to exert monopolistic muscle through becoming 'national champions'. This effort rather disintegrated thereafter as forces of globalization demanded the rise of 'international champions', leaving the old national monopolies stranded. Moreover, countervailing forces to do with anxieties about innovation, employment, autonomy, etc., appeared to warrant support for SMEs. There is some evidence from admittedly rather confused data suggesting that both small and large firms may be best for innovation (e.g. Pavitt et al., 1987, based on the SPRU innovation database for 1945-83), but at the same time medium levels of concentration could be best, to avoid the contrasting inefficiencies of lack of power in fragmented industries and lack of incentives in monopolistic industries (Kamien and Schwartz, 1982).

4) Knowledge base: There were belated concerns about declining numbers in STEM subjects (science, technology, engineering, mathematics), though attempts to solve the problem through government intervention were either inadequate – in the sense of having little visible impact – or excessive, as students were lured into fields such as 'computer studies' in the later 1990s and early 2000s, only to find that the jobs to employ them were no longer present.

The sectoral data provided in von Tunzelmann (2003) indicate a squeeze on R&D in high-tech sectors apart from pharmaceuticals – most evident in sectors like aerospace (facing some withdrawal of protected home markets as the government cut its defence budgets) and electronics (loss of innovative competitiveness), despite the production shares of the UK holding up in these sectors. The implication was one of a loss of power to foreign-based MNCs that used their technological strength to take over much of the UK production.

Even more significant is that these figures overlook the rising share of R&D in services, amounting to as much as one-quarter of the total by the later 1990s (Boden, 1998). The report from NESTA (2006) dwells on the importance of many service sectors to the UK economy, and the comparative unimportance of traditionally measured R&D in those sectors, even though some impact has become evident. Whether the UK success in financial services outlives the current financial crisis remains to be seen.

4.3 National learning systems and technological capabilities

According to our dynamic capabilities approach, there are key distinctions to be drawn in principle and in practice between ‘competencies’ and ‘capabilities’, with the former representing resources, like the classical ‘holy trinity’ of land, labour and capital – in which case most of the upgrading of the knowledge base comes about before the stage of production in firms, and takes place in upstream suppliers such as universities. In the case of capabilities proper, the enhancements are to the ‘services’ the activity produces, and for the most part come about within the producing firms themselves, in their innovations for each of their 5 functions (process innovations, product innovations, etc.). Observe, however, that the enhanced competencies of firms rest here on capabilities exerted further upstream in the supply networks – e.g. in universities out of their capabilities to supply tertiary education or in other countries for capital inflows into the UK via MNCs.

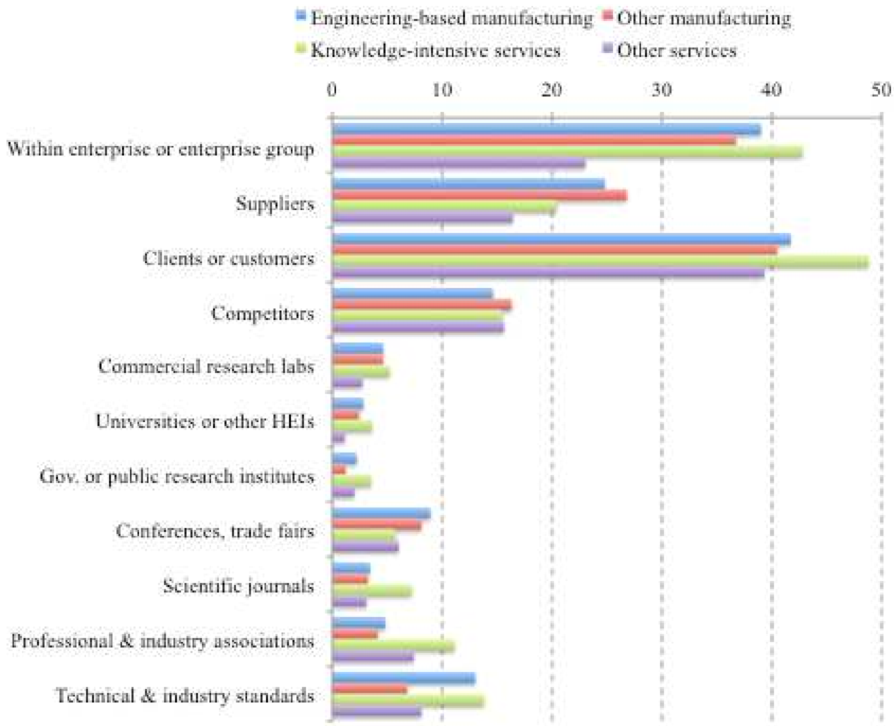
Capabilities in firms. In terms of broad aggregates, the highly important information for innovation in the UK manufacturing and service sectors, according to CIS data, comes essentially from primary stakeholders and within the firm, in the period 2002-2004. As figure 4.3 shows, the main source of information for innovation for both sectors is clients/customers were the main source of information or innovation, ranging from almost 49 in the knowledge-based services to about 41 percent in manufacturing. Information from within the enterprise or enterprise group was the second most important source of information in all of the industry groups. The third and fourth sources were network related, i.e. suppliers and competitors. Interestingly, around 13 percent of knowledge-intensive firms reported regulations and standards as highly important sources of information, followed by professional associations and other market and institutional sources of information.

Innovation capacity – exploration vs. exploitation. R&D personnel have been growing steadily in the UK in the period 2000 to 2008. The increase exceeded that of the total employment growth. Moreover, the increase was more noticeable in the R&D Technician and Support Staff, implying that exploitative capacity is relatively gaining importance in the UK compared with explorative capacity in UK R&D innovative activities.

The number of Researchers is taken here to represent – somewhat crudely it has to be admitted – the explorative capacity for an organisation or nation, and the number of R&D Technicians and Support personnel represents the exploitative capacity, then the exploitation to exploration capacity ratio in the UK increased from 0.8 to almost 1.0 in these years (see Figure 4.4).[8]

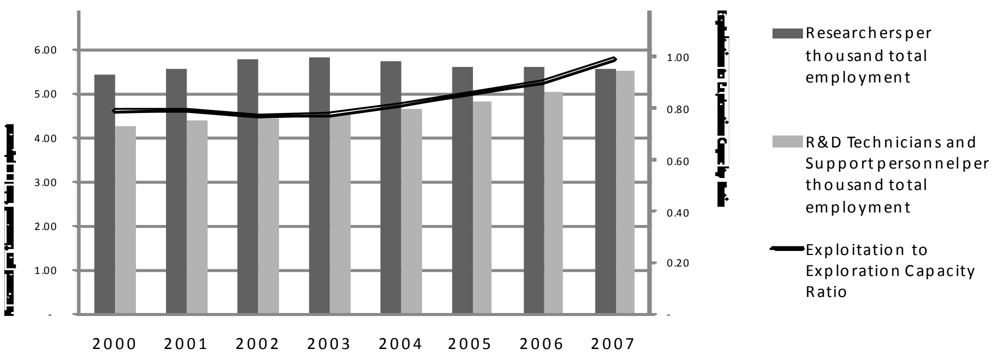
[8] This indicates that by 2007 there was similar capacity to exploit as to explore innovative activities, whereas in 2000, there was 20% less capacity to exploit than to explore.

Figure 4.3: *UK Sources of Information for Innovative Activities: Selected Industries, 2004-2006.*



Source: UK Community Innovation Survey 2007.

Figure 4.4: *UK R&D Personnel and Exploitation to Exploration Capacity Ratio*



Source: based on data from UNESCO

Competencies of UK firms – Human Resources. The patterns of total employment in the UK show a procyclical decline in the early 90s, followed by a sustained if rather slow rise from about 1994 to the end of the century, and then comparative stagnation. This total can be broken down in several different ways.

1) By gender: the trends for male and female employment are similar, except that numbers of females do not fall in the early 90s – suggesting in turn that cost-cutting substitution of 'cheap' female for more expensive males was uncommon except perhaps in periods of recession.

2) By age group (distinguishing 3 age-groups): the data indicate that the younger worker (15-24 years) found it harder to get work, their employment rate dropping from about 70 percent ca. 1990 to a figure around 60 percent by the mid-90s and later even less (though additional education was among the positive factors operating here). Meanwhile the rates for older employees (over 55 years of age) are increasing from the mid-90s, and reaching 60 percent participation by the early 2000s; and the employment rate for 'standard' employees of 25-54 years cycling gently around 80 percent.

3) By self-employment: Contrary to widespread popular impressions of growing self-employment and casualization of labour, the figures to hand suggest a sizeable decline in self-employment over these two decades, and of similar proportions for both males and females.

The rates of total unemployment from 1990 exhibit a rise till early 1994, followed by a sustained fall through most of the subsequent years until 2007 (note that subsequent rises during the financial crisis are not included here). The fall for males is slightly larger than for females. The drop in the long-term unemployment rates was decidedly larger to 2007. For the year 2005, when the national average stood at 5.4 percent, the regional differences ranged between a minimum of 1.6 percent and a maximum of 10.1 percent.

Tertiary education. Total graduates from UK tertiary education, considering all the full- and part-time programmes in public and private educational institutions, increased by as much as 36.8 percent from 1999 to 2007. The number of graduates in science rose by 28.4 percent, whilst those in engineering fell by -2.1 percent; thereby offsetting the happy picture portrayed above of a shift from exploration to exploitation over these years. More precisely, if there was in fact such a shift, it was accompanied by a likely relative decline in the average quality of the human resources under 'exploitation'.

Total enrolment in UK tertiary education increased by a smaller proportion – reaching 13.5 percent over the same span of years (1999-2007). There were significant expansions of enrolments in Education (56 percent), Humanities and Arts (60 percent), and – lagging a little way behind these – the more commercial subjects of Social Sciences, Business and Law (37 percent). The enrolment in tertiary education in the programmes for the STEM subjects (Science, Technology, Engineering, Mathematics) showed much slower rises of around 11.2 percent in Science and 8.8 percent in Engineering, which gave concern to a series of governments about the diversion of talents away from traditional strengths. Enrolment in Services from 2004 to 2007 records a powerful increase.

As a proportion of total educational expenditure, the expenditure on tertiary education from 1999 to 2006 fluctuates between 17 percent and 22 percent around a stationary trend. However, that former level regarded as a proportion of total government expenditure shows a modest but relatively steady rise. Moreover, public expenditure on education as a percentage of GDP demonstrates significant growth, amounting to 22.6 percent over these years. To a slight extent this result is offset by a small decline in total tertiary expenditures from private sources.

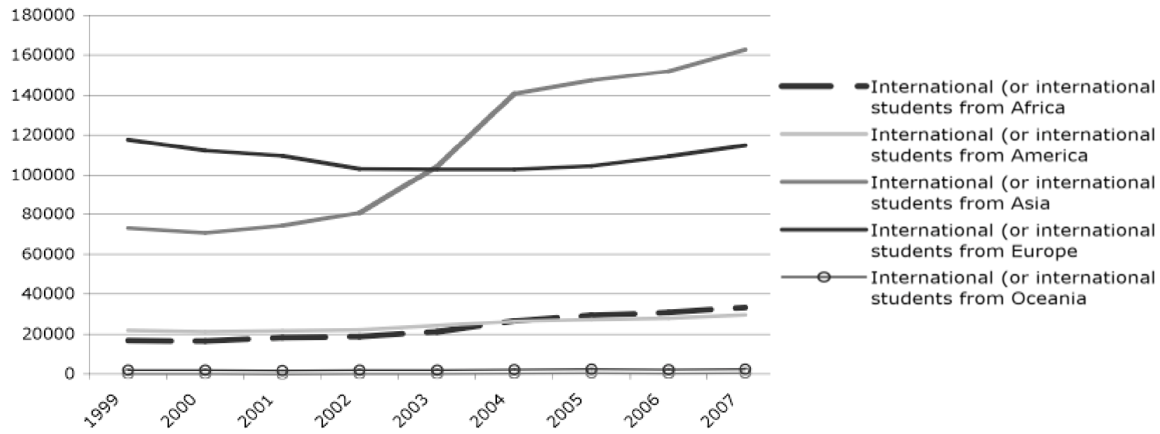
4.4 Knowledge flows and networks in the UK's national innovation system

International flows of students. Numbers of international students coming to the UK rose rapidly over the years from 1999 to 2007, with all of the increase of 51.1 percent coming in the years from 2002 onwards, and especially in the two years of rapid growth, 2002 to 2004. Female students accounted for almost exactly half of this increase, recording a slightly higher growth of 54.7 percent.

Figure 4.5 illustrates the distribution of students by continent of origin. In terms of total numbers, the patterns are dominated by two contrasting trends: one for Europe which begins as the largest source, based on low access costs, but then its numbers decline to 2004, and are not fully restored by 2007. Far and away the largest gains are recorded by Asia; whereas in 2000 Europe exceeded Asian levels by some 50 percent, by 2007 the situation was reversed. The gains for Asia took off in and around 2002, with a more levelled off gain from 2004 onwards. Many of the additional Asian students were coming from China; indeed the UK government began to believe that it had wrested control of Chinese outflows for students away from the USA. The numbers coming from India also rose very sharply. Further down the chart, Africa overtook the Americas as a source.

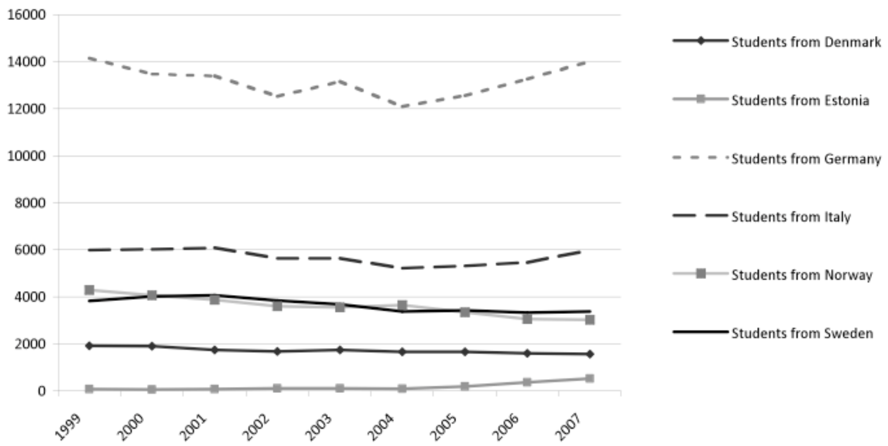
Figure 4.6 charts numbers of international students in the UK coming from the countries participating in WP3. Levels differ according to country size plus cultural-linguistic differences, though most patterns mimic the total for Europe set out in the previous diagram. The impact of access factors changing is shown by the series for Estonia at the foot of the chart – virtually zero before accession to the EU in 2004, when the present second author's own Estonian students must have accounted for a significant portion of the subtotal, they rise perceptibly thereafter.

Figure 4.5: *International students in the UK by continent, 1999-2007*



Source: Based on data from UNESCO Institute for Statistics, Education 2010.

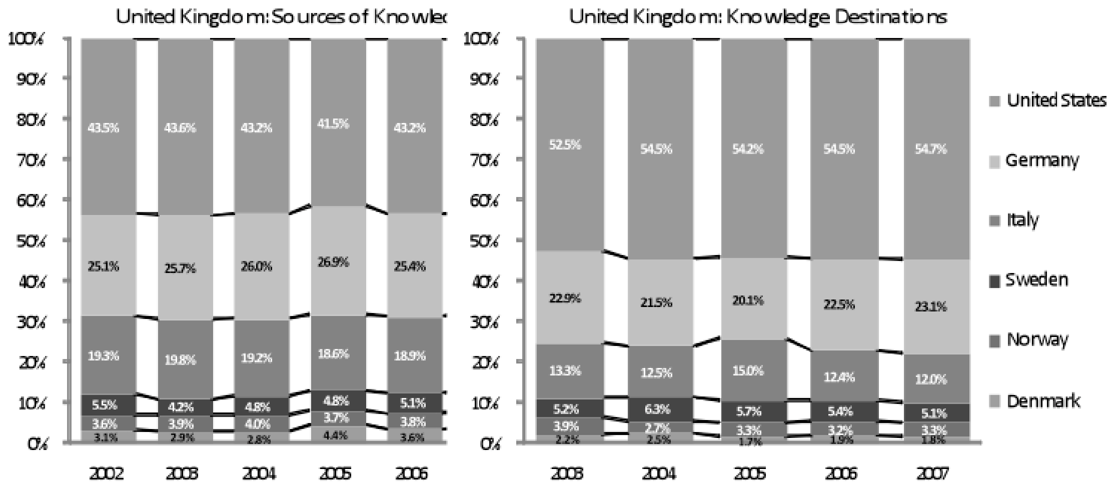
Figure 4.6: *International students in the UK by EU country, 1999-2007***.**



Source: Based on data from UNESCO Institute for Statistics, Education 2010.

Trade in Goods and Services. Trade is often regarded as providing only a weak form of integration, precisely because of its oft-stated aim of attaining higher levels of international division of labour through the exercise of comparative advantage. Consequently trade is usually seen as entailing 'shallow' rather than 'deep' integration. There is a clear negative trend of the trade balance of goods for the UK, but the trade balance in services increases steadily and very significantly, recording a growth of 630 percent measured in USD between 1990 and 2007. The rapid expansion in imports and exports of services is often compared to and sometimes almost equated with international exchange/flows of knowledge. The main source and destination of such 'foreign knowledge' is the United States, followed by Germany and Italy. Figure 4.7 gives some information for the UK together with other EU countries covered in the report. Although the USA records the lowest of the percentage increases, it remains the largest source and destination of trade in services for the UK.

Figure 4.7: *UK Sources and Destinations of Knowledge-oriented Services*



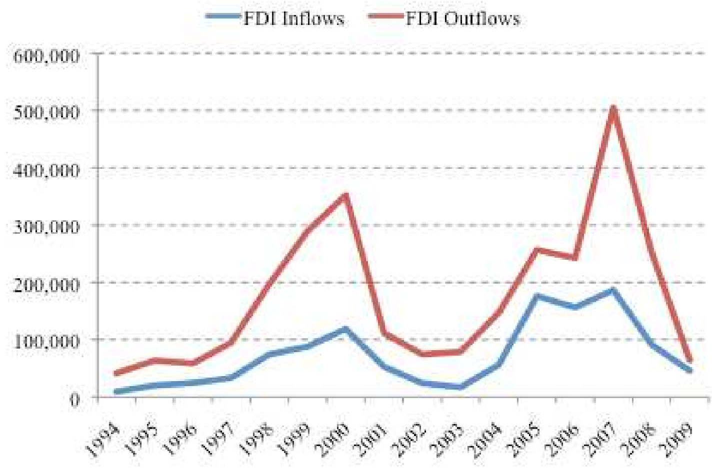
Source: Based on data from OECD, Country Statistical profiles 2009.
*Excludes Transportation and Travel Services.

International flows of capital. The UK economy had attracted important amounts of foreign direct investment (FDI) in the second half of the 1990s, when it rose from 1 percent of GDP to 8 percent by 2000. After a sharp decline in the early 2000s, UK FDI inflows then recovered strongly. Notably, the share of FDI in gross capital formation (GCF), although fluctuating significantly was growing from 2002, which in turn suggests long-run growth possibilities for the UK through enhancing its competencies (Hansen & Rand, 2005).

Figure 4.8 indicates the UK inflows and outflows of FDI in millions of US dollars from 1994 to 2007, showing a positive correlation between inflows and outflows. Although the percentage rise in inflows is larger thanks to the low initial base in 1994, the outflows dominate the cyclical patterns in the late 90s and again during the troubled years from 2007. Inward inflows of FDI from the EU15 and EU25 reveal high fluctuations around a positive growth trend. Amounts fall off after 2005, though only Denmark shows an absolute decline in this period. At the same time, Denmark has the largest percentage gain in outward flows of UK FDI, proving that the links at the global level between outflows and inflows do not carry over to the national level. Conversely Estonia shows the largest absolute decline in percentage terms of outflows and the largest increase in inflows.

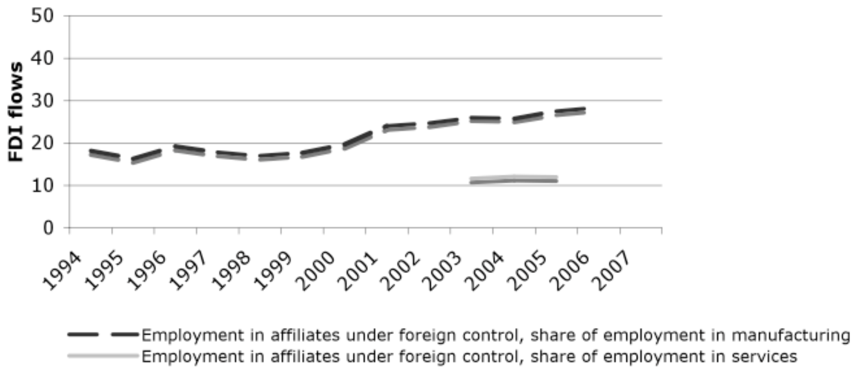
Figure 4.9 maps out the activities of multinational companies in terms of employment share in affiliates under foreign control in manufacturing and services from 1994 to 2007, expressed in millions of US dollars. Even though the comparison is feasible from 2003 to 2006, it seems that the employment share in manufacturing is higher than that in services. Additionally, the former presents a relatively steady trajectory, recording a substantial increase of just over 75 percent in these years.

Figure 4.8: *UK inflows and outflows of FDI, 1994-2009 (US dollars, millions)*



Source: UNCTAD, 2010 World Investment Report.

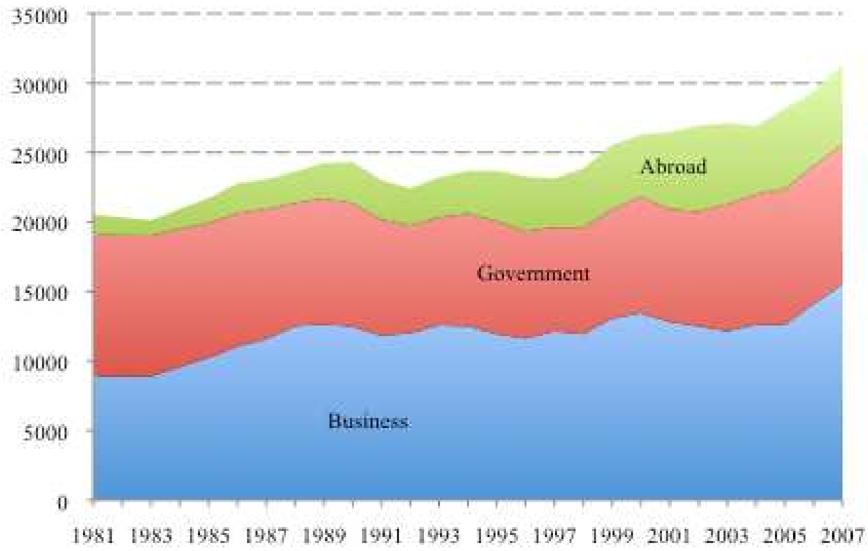
Figure 4.9: *UK employment share in affiliates under foreign control, 1994-2007, share of total employment.*



Source: based on data from OECD, Country Statistical profiles 2009.

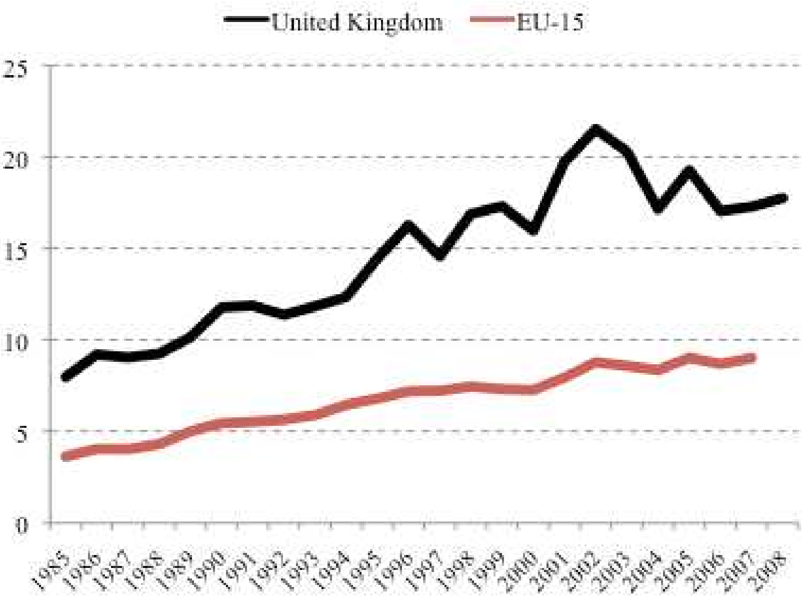
Internationalization of R&D. The internationalisation of investment and knowledge flows in the UK has also had an effect on its capacity to attract funding for Research and Development activities. The share of GERD financed internationally has grown since 1985 when it represented 8 percent of the total, doubling that by 2007 to reach 17.5 percent. Figure 4.10 shows that finance from abroad is an important source of funding of R&D activities in the UK. And Figure 4.11 shows that it is significantly above the EU-15 average and gaining in relative importance over the years. Because of the size of the economy, the EU-15 average is not very different from the EU-27 average.

Figure 4.10: *Sources of finance for R&D activities in the UK, 1981 to 2007*



Source: Based on data from OECD, Main Science and Technology Indicators, December 2009.

Figure 4.11: *UK share of GERD financed from abroad relative to the original EU 15 Member States.*



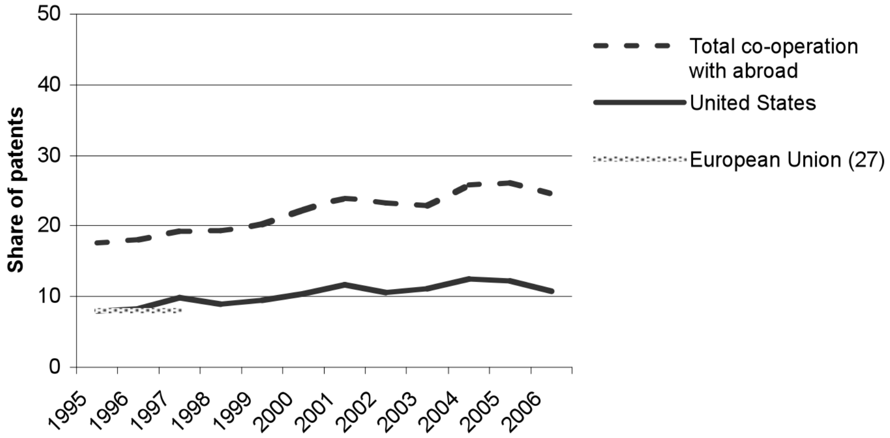
Source: Based on data from OECD, Main Science and Technology Indicators, December 2009.

Collaborative patenting. Evidence on patents is a very restrictive way of thinking about our principal subject, and that one of the main aims of the INGINEUS project is, or should be, to find superior methods and methodologies to reassess the scale of innovation in complex organizations, let alone its determinants. Nevertheless it would seem meaningful to evaluate UK international cooperation in terms of share of patent applications to the EPO (European Patent Office) under three main headings: owned by foreign residents (which grew in total by nearly 18 percent from 1995 to 2006); invented abroad (grew by 11 percent); and those with foreign co-inventor(s) (again grew by almost 18 percent).

The first category, of foreign-owned but UK-located patents, rises slowly until about 2004, after which it declines a little. As between US and European sources, the latter own only about half of the former in the initial year, 1995, but catch the US up by 2003. In the second category of inventions abroad, the shares remain more or less the same throughout, with the EU pulling ahead of the US after about 2001. Figure 4.12 maps out the share of patents with foreign inventor(s) from 1995 to 2006, showing a somewhat unsteady increase. In addition to the greater increase of the EU-27 as compared with the US there are also some very rapid increases for individual countries, such as India, China and Brazil. Norway has a slight decline, perhaps due to some fall in oil and gas areas.

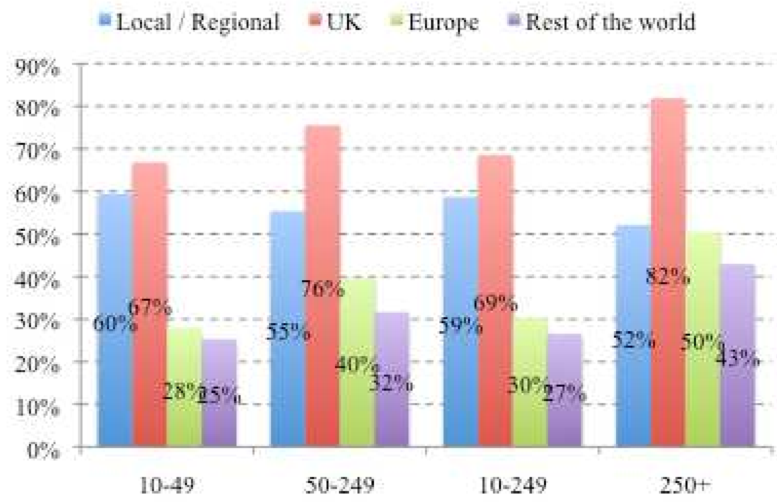
Global collaborative networks. The following analysis is based on the UK Community Innovation Survey (CIS4), whose data cover international innovation network collaborations of the UK from 2004 to 2006. Such international collaborations by UK firms are more often informal than formal. Figure 4.13 shows that the international cooperation agreements follow the same trend as the international markets, which were directed in the first place to European partners, and secondly to the rest of the world. The data here indicate a pattern of rising concern with international agreements as firm size grows – which seems hardly surprising – but with shares that increasingly favour European partners, which is less intuitive.

Figure 4.12: *UK Share of patents with foreign co-inventor(s), 1995-2006*
EPO application by priority date



Source: based on data from OECD, Country Statistical profiles 2009.

Figure 4.13: Share of *UK shares with cooperation agreements by location and firm size, 2004-2006.*



Source: Based on data from CIS, UK Innovation Survey 2007 Statistical Annex.

Whilst all sectors sign cooperation agreements with European partners, the knowledge-intensive services sector signs mainly with the Rest of the World rather than with European partners. There are substantial differences between sectors in respect of the shares of firms with agreements; the main determinant being their position in the supply chain, with the primary sector thus leading the way. Porter argued that in order to compete in a globalised economy UK companies must raise their productivity to compete in "more unique [sic.] and more innovative products and services". Yet, according to the former DTI, which sponsored Porter's studies, the UK has performed quite successfully in innovation networks and collaborations, being placed ahead of Germany and behind France in 2006. In recent times, the UK government has been aiming at boosting the 'private investment chain' and developing deeper interactions between fund managers, firms and capital markets. Additionally, enhancing skills and promoting knowledge transfer may help to achieve those aims.

Although British universities and business have enhanced their mutual relationship, the communication channels between them needs to be reinforced through a clear exchange of information regarding either the business needs, or the comparative research abilities available (DTI, 2006, pp. 34-45). Moreover, despite UK firms exploiting many network relationships, there is still some discrepancy between sectors and regions (d'Este et al., 2010), making the overall UK network infrastructure fragmented, and prone to short-termist decision-making (see section 5 below on governance).

Whilst the users offer major information regarding the function of the products linked to their current and emerging needs, the manufacturers contribute to innovate through enhancing noted needs. However, this may work differently for small firms who pay more effort to develop networks, and have lower quantities of external transactions etc. as is underlined in the Lambert Review(DTI, 2005, pp. 49-50; Lambert, 2004).

4.5 Governance of technology

The principal argument that has been developed in many countries for supporting important government activities in the arena of Science and Technology (S&T) emerges from notions of 'market failure' – left to themselves, markets would not allocate sufficient resources to the advancement of S&T from an economic and social point of view. Our approach to this large question involves reconsidering at much the same time both the internal dynamics of firms and on the other hand the external dynamics, of networks and other forms of broader governance, extending to multiple agents working at various levels of the polity. We read into this our notion of dynamic and interactive capabilities as the link between these micro and meso-level concerns.

Technology and organization – Internal aspects of coevolution. The claimed weaknesses of British forms of industrial organisation, governance and management have been detected in a number of ways, apart from allegations of sheer managerial incompetence that are hard to substantiate in terms of any aggregate impact. Since this paper has laid some store on governance issues, a brief consideration should be given to some of the arguments set out here.

1) Delayed introduction of the 'M-form' (multi-divisional) corporate style – this was the view put forward by the business historian Alfred Chandler (in Chandler et al., 1999), that British firms clung too long to obsolete corporate structures such as the 'U-form' (unitary), which were too unfocused for an era of multi-product companies selling their products to a variety of markets. However, while this may be a valid criticism of UK corporations in the early postwar years, in the days when large capital structures were dominant, the product-oriented multi-divisional form itself became too rigid for the ensuing years when companies came to be not just multi-product and multi-regional, but multi-technology (Granstrand et al., 1997). More specifically, the M-form could become a source of rigidity in a period when corporations were aiming to develop ICT-based systems.

2) Short-termism through myopic decision-making systems (e.g. Patel and Pavitt, 1988) – this argument holds that UK companies were particularly prone to avoiding long-term strategic decisions such as those to invest in major new technologies, under the pressure of powerful financial capital interests together with voracious demands for dividends by their shareholders. Companies such as the electrical equipment firm GEC (General Electric Company) preferred at times to accumulate monetary savings and place them in the stock market rather than reorient themselves to the new era of ICTs.

3) The 'market for corporate control' – such a market for corporate ownership led to aggressive takeovers and asset-stripping, as exemplified by the manoeuvres of wealthy industrialists such as Lord Hanson. In this case the kind of market involved, so far from 'failing', worked all too well.

Innovation and network alignment – the meso level. Observing the picture of UK innovation collaboration networks based on OECD and CIS data, there are several nascent issues that indicate network alignment and misalignment as between the national and international levels. Firstly, at international level, the UK government in identifying the innovation drivers and their indicators, includes the patents granted by the United States Patent and Trademark Office (USPTO), however, the total patents trends: owned by foreign residents, invented abroad and with foreign co-inventors are significantly and strongly negative, and its growth rate equal to more than - 90% from 1995 to 2006 for the three cases. Therefore, it would be more useful considering any other innovation indicators measuring the UK total patents granted; in addition, it would be necessary working on what are the reasons of such negative performances and increasing the patents applications granted by USPTO. Secondly, at national level, following the CIS logic regarding the firms analysis we consider them by size, sector and region. It seems that there is a correlation between the firm size and the quantity of innovation networks collaboration, this is evidenced by the fact that larger firms record a higher number of networking activities, such as for the co-operation agreements; whilst small firms record a lower number of networking activities.

Nevertheless, things change in terms of profits, as there is evidence showing that small firms not only have cooperative agreements with clients and high shares in terms of science and technology skilled employees, but even record higher turnover of innovative products than larger firms; in effect this may be explained by the fact of employing such high skills. Thus, regarding with small firms these two conditions (cooperative agreements and science and technology skilled employees) need to be satisfied in order to achieve higher turnover of innovative products. Consequently, as the first aim of a firm is gaining profits, the small firms perform better than those larger, which, we have seen, can easily access and be involved more likely in network collaborations than the smaller.

If we consider the sectors, the scenario keeps similar, although it is possible to identify engineering-based manufacturing and knowledge-intensive services as the most active in terms of cooperation agreements and innovation activities. In fact, we find that in those two sectors, the most innovative active firms are those with higher share in: main innovation activities, such as: technological and knowledge acquisitions and extramural R&D, product-orientated effects and increased added value. However, knowledge-intensive services record a higher share of skilled employees (science and engineering/other degrees), surprisingly followed by the primary sector rather than by engineering-based manufacturing.

Looking at the geographical dimension we see that whilst North West of England performs better in terms of cooperation agreements; the South East of England has better performances in terms of sources of information with clients and chain partners. Further, on the one hand, there is alignment in terms of cooperation networks: most of the sectors have cooperation agreements with European partners, also operate mainly in European markets. On the other hand there is misalignment as although the knowledge-intensive services record main cooperation agreements with the rest of the world, their main market is European.

Similarly to the sector analysis, London shows misalignment in relation to the presence of cooperation agreements or global collaboration networks with the rest of the world, whilst its main markets are European. It is a misalignment in the sense that the main markets are supposedly the main informal knowledge networks for the firm. Additionally, looking at the firm size, alignment is present between cooperation and markets (informal knowledge networks, i.e. producer-users) for large firms, whilst there is misalignment between cooperation and markets for small and medium firms. Whilst, looking at the sectors there is alignment between cooperation and markets for those following: other services, knowledge-intensive services, construction, and engineering-based manufacturing. Whereas, misalignment is found between cooperation and informal knowledge transfers-producer-user interactions (markets) for: primary sector, other manufacturing, and retail and distribution.

Finally, considering the regional dimension, it is evidenced that misalignment is presents in all the regions, except for Scotland and Northern Ireland, which have local cooperative agreements and supply local markets; hence, the cooperation agreement is complemented with informal knowledge networks based upon producer-user interactions, whilst the rest of the regions are not able to match these two knowledge exchange process, i.e. formal and informal.

Economic growth and technology policy at the macro level. More precisely, an extensive literature in economics that dates back at least to the classic studies by Nelson (1959) and Arrow (1962), later refined by the 'new growth' theorists like Romer (1986, 1990, 1994), has contended that markets will under-invest in R&D when there is: a) incomplete appropriability ('non-excludability') – that is, firms cannot keep all the benefits of their research to themselves, as knowledge leaks out to others; b) non-depletability ('non-rivalry') – i.e. the results of R&D can be used by others without incurring real resource costs. However, in practice, the costs of imitation may be much higher than implied by the new growth theorists, casting doubt on the free-lunch nature of any technological 'spillovers'.

The major shift of emphasis in 1970s/80s implied that government technology projects then had to justify themselves using 'market-failure' or at least 'market-friendly' criteria. This went alongside a rather curious loss of popular faith in the properties of technology to redeem growth performance, which arose (at least in part) for the following reasons:

1) a continuing loss of British competitiveness in 1960s/70s in what were regarded as technology-based industries.
2) a sequence of public relations disasters, e.g. nuclear power, and later BSE ('mad cow disease'), for which the government was perhaps only partly to blame (Henderson, 1977; van Zwanenberg and Millstone, 2005).
3) many high-tech companies turned into financial flops, i.e. became specific corporate failures, particularly as the dot.com bubble burst in the early years of the present century, though with a considerable number of predecessors, like ICL in computers.

The correspondence between such loss of public respect for technology and an intensified desire by the UK government to obtain 'market-friendly' outcomes led to a partial withdrawal of government support for technological objectives, after a high-water mark in the early 1980s. The consequences will be expanded on below, after giving some brief attention to the UK's track record in technological performance.

The case for government intervention via technology policy in the UK in the later 20th century was typically justified by 'market failure' arguments. In several recent papers I have argued firstly that an analysis of technology trends indicates that non-market failures, mainly systemic and dynamic in nature, were a more basic source of British technological shortcomings. Secondly, an analysis of trends in technology policy suggests that narrowly economics-based views too often hampered good intentions to reform policy along more appropriate lines, and restricted development of any serious capabilities for 'policy learning' in the field.

According to Barber and White (1987), the chief forms of 'market failure' invoked by policy-makers in the UK government department responsible in the mid-1980s for technology policy – the Department of Trade and Industry (DTI) – were as follows:

1) Risk – firms were too often risk-averse to carry out R&D projects, even when they stood a good chance of succeeding;
2) Information – asymmetries of access to relevant technological information existed, especially for small and medium-sized enterprises (SMEs);
3) Competition and market structure meant that high R&D costs often acted as entry barriers against newer entrants;
4) Externalities – especially the non-appropriable benefits from spillovers to competitors.
5) 'Dynamic' elements, as these writers term them – particularly secular changes such as 'infant industry' and 'infant technology' situations.

Barber and White stress that such a list was incomplete from a theoretical viewpoint, and indeed that policy-makers did little to interact with economic theory (it should be noted that John Barber was at the time and until his recent retirement employed by the DTI). But how appropriate was contemporary theory in any case to the growing emphasis in policy (and practice) of collaborative research/R&D (a pattern to be described below)?

The principal claim made in this paper is that many of the 'failures' that have been in operation in the actual British context in the postwar years have been 'non-market failures' rather than the above (or more extended) list of market failures, and in addition that many of the presumed market failures as diagnosed in reality concealed deeper 'non-market failures'. Hence our first task is to attempt a categorization of 'non-market failures', whose character might appear less immediately apparent. To do so, failures as well as 'successes' can be related to each main type of governance mode. For present purposes, the economical definition of 'governance' provided by Prakash and Hart (1999) is taken as adequate – governance is "organizing collective action".

The literature seems to recognise four main modes of governance, namely markets, hierarchies – of two kinds, corporate and government – and networks (e.g. Thompson et al., 1991). For present purposes, I define 'networks' in a residual and somewhat negative way, namely all interactions between or among agents that do not involve power relations or market exchanges. To each mode there corresponds a particular form of failure, and both the mode and its negation in the associated form of failure is frequently classified as a kind of 'hand', in tribute to Adam Smith's 'invisible hand' to describe the market mode.

It needs to be stressed that, in practice, few if any significant real-world situations reflect a unique mode of governance, but our theoretical models for dealing with complexity in governance (like conjoined corporate and government modes or forms of failure) are practically non-existent. This is most evident for the case of networks, few of which in reality do not involve additional elements of power relations or of monetary exchange, though not necessarily all at the same time.

All of us are involved in multiple networks, as a measure of the complexity we face – networks of academic disciplines, of work-based organizations, of policy-makers, of kinship, etc. We can thus think of 'networks of networks', for each individual agent – and individuals come together to form organizations and institutions, as compound agents. Just like other forms of governance, networks are subject to 'failure', and these network failures can involve:

1) a required network being missing or very ineffective (specific failure, as studied in much ‘social network analysis’);

2) an existing set of networks that pursue antisocial targets (systemic failure in goals);

3) an existing set of networks that pursue socially acceptable targets but in inconsistent ways (systemic failure in instruments).

Of these, the third type is the most elusive but probably the most important. They generate issues that are being studied by the ‘network alignment’ approach. Thus in my Revue d’Economie Industrielle paper of 2004, I paid particular attention to the mismatch between the EU’s macroeconomic policy, as a restrictive set of policies under the flag of the Stability and Growth Pact and the associated Maastricht criteria, and its technology policy, as a set of expansionist policies grouped around the Lisbon Agenda of 2000 and the associated Barcelona target of raising the rate of GERD intensity to 3 percent of national income. While two-thirds of the supposed 3% target was supposed to come – somehow – from the private sector, it was, and still remains, difficult to see how such an expansionary rise in R&D could come about in a constrictive macroeconomic environment. To account for the network dimensions of this issue however requires some further consideration be given to the nature of the relevant ‘system’.

The kinds of systems that are indeed relevant here are the ‘techno-economic systems’ portrayed by Freeman and colleagues (e.g. Freeman and Perez, 1988; Lee and von Tunzelmann, 2005; von Tunzelmann et al., 2009). The evolution of such techno-economic systems over the longer term has been driven by:

1) technical drivers on the supply side;

2) economic drivers on the demand side;

3) the interfaces between the technical and economic drivers; and

4) cross-currents of ‘complexity’, that are i) spatial, especially globalization, ii) functional, especially new technologies.

Networks are offered as a generic solution to the emerging problems of such complexity, because they enable appropriate linkages to be made, especially where the context of ‘networks of networks’ can thrive. ‘Pure’ networks, involving as already stated interchanges among agents that do not (principally) concern power or market relations, arise most often in situations of exchanges of knowledge. This occurs because of the combinatorial properties of much knowledge (i.e. joining rather than supplanting, or complementary rather than competitive), together with the difficulties of valuing knowledge in markets.

The network alignment approach accepts this ‘solution’ to many contexts of complexity, but does not find it unproblematic. Among the problems that the resort to networks throws up are the following (this list is by no means exhaustive):

1) Practical problems of managing and organizing networks – contrary to much of the literature such networks do not simply organize and manage themselves, and the absence of a hierarchical or market mode of governance actually intensifies the problems to be dealt with, especially in the common context of ‘networks of networks’, where a given network organizer is likely to be managing one or two of the relevant networks while being managed in regard to the others. Building the trust and reciprocity

normally required in a situation where overt power relations are ostensibly limited or non-existent calls for the exercise of tact, care and wisdom. Nevertheless the concern in this paper is with more analytical issues, which in part are responsible for the problems of managing networks.

2) Measuring knowledge, as the likely content of what the network interchanges – there are well-known limitations of the data extracted from such sources as innovation surveys, patents, R&D, or skills as guides to assessing the effectiveness of the networks in question; to say nothing of the problems involved in trying to gauge tacit knowledge, absorptive capacity, etc. (Giuliani, 2007).

3) Assessing the network goals (targets) immediately runs into problems of overlapping and often conflicting goals for each agent in the network; for instance for firms (where the goals may be variously market-seeking, cost-seeking, or knowledge-seeking), for universities and other higher education institutes (goals may be to expand research, teaching, or revenues, say via IPRs etc.), for governments (political goals of a regulatory, developmental, or distributive nature), and so on. Problems of making these compatible in multi-agent networks are of course often very serious.

4) Measuring network capabilities – matching 'network structures' and knowledge structures (the instruments to achieve such conflicting goals, for knowledge creation, dissemination or interaction, e.g. through bridging institutions). Again the problems accumulate in multi-agent environments, e.g. for the higher education sector, which is expected to supply science and technology to firms but also some policy advice to governments.

5) Assessing the dynamics of knowledge accumulation – attaining the dynamic economies of scale and scope (increasing returns) involved in recompensing the system for the burdens imposed by networking. These are likely to involve time-saving and space-saving effects (issues of 'when' and 'where', to add to the usual list of 'what', 'how', 'who' and 'why').

The complete attainment of 'network alignment' is an improbability, given the multiplicity of goals, instruments, agents and networks involved. It is quite likely to be undesirable to reach any such optimum, because the costs of striving for perfection at the margin may well exceed the benefits. Nevertheless, at the heavily infra-marginal level at which most existing network structures probably operate, there is often much to be said in favour of aiming to do better – rather than achieving 'best practice' I would thus follow evolutionary thinking in advocating the objective of 'better practice'.

The most evident change in governance over the period – in the UK as in many other leading countries – was the shift in its main thrust from being primarily government-led in the 1950s and 1960s to being primarily market-led in the 1970s and especially 1980s. Although the 1980s was associated with the pro-market Thatcher regime, both Labour and Conservative administrations shared these patterns. These were followed in turn by a more mixed set of views giving greater emphasis to collaboration in the 1990s, with decentralization in the most recent decade, reversing the somewhat inconsistent Thatcher trend towards increased centralization.

The primary deficiency of the British economy in regard to its innovative performance – at least so far as the technological dimension is concerned – over the years from the 1960s to the

1990s thus arose in relation to the private sector of industrial business. It is there that one must begin the search for sources of 'failure', even if as already strongly implied the failure turns out to be systemic at heart. Several candidates have proven popular in this respect.

'Policy design' represents the ways in which multiple layers of systems are individually and collectively structured and controlled to yield benefits – good policy design is, in part, the expression of a satisfactory alignment process. With this in mind, Freitas and von Tunzelmann (2008) test a three-dimensional model of public support design – vertical/horizontal knowledge objectives, specific/general support provided, and local/central implementation – as a framework to characterise and compare national policy incentives. The paper compares 149 policy programmes in the UK and France from the early 1980s to 2002.

Despite the two countries having different national innovation systems, the role of policy-making in both became increasingly recognised as a provider of market incentives to new and/or better business-to-business services markets. Both the French and the British public business support became more non-financial each time policy was redesigned, and increasingly concerned with innovation. More specifically, until the mid-1990s, the French portfolio of innovation policies concentrated more on the use of local support frameworks and local services structures, while the British showed a greater reliance on label creation (setting quality standards etc.) and central financial subsidies.

In the UK, the introduction of value-for-money and 'hands-off policy execution' principles in the public sector delayed the process of decentralisation of public business support – before the mid-1990s most horizontal public support consisted of specific types of support centrally delivered, but from the mid-90s a change can be observed towards more local implementation and the provision of general support. It is also worth observing that, at least in our dataset, most of the British programmes do not last for more than one sub-period – on the contrary, most of the French programmes launched in the first (1980/88) and second (1989/94) sub-periods were still active in the final period (1999/2003). Whether this implies a lesser stability in British policy-making or a greater willingness to take on new challenges (or both) must remain for others to assess.

The role of interactive and dynamic capabilities in policy-making. In complex structures such as national innovation systems, there is no a priori guarantee that the capabilities of one type of agent (say firms) evolve in the same direction as those of another type of agent (say household consumers). First, in accord with a classic market failure issue, asymmetries of information may take them in different directions. But second, and more broadly, 'asymmetries of knowledge' may prevent them from going in the same directions, even under the supposition that both parties are blessed with perfect information.

Without going so far as to presume the existence of perfect information, the significance of such asymmetries of knowledge is enough to propose that interaction among the relevant types of agents may be necessary, whether ex ante, through knowledge exchanges, or ex post, through market exchanges. Thus a typical motor vehicle assembler engaged in contracting out the manufacture of individual components to its suppliers will usually begin with a phase of knowledge interaction between them to settle details relating to the parts in question, before purchasing those parts through market mechanisms – the assembler will already have resolved the matter of quality control etc. before paying for the items delivered.

Different agents (whether they are different firms or – say – different levels of government) have differing capabilities for interaction – the ability to learn from such interaction and to absorb the lessons, and then to 'recycle' their products into the system. In the case of governments, the 'products' we are concerned with are policies and their design. In the same manner as firms (and universities), governments have differing competencies and dynamic capabilities to react to and direct change, as exemplified by the crucial role of 'vision' in East Asian governments (von Tunzelmann et al., forthcoming).

The prevailing context of what Schumpeter (1934: 64) called 'dynamic competition' means the environment (landscape) may be constantly changing. This entails interaction of the kinds hinted at above occurring in 'real time'. The extent to which the interactive capabilities of governments are 'dynamic' is therefore dependent on the degree to which their policy sources and/or impacts are not only novel but also appropriate to the changing environments in which they are positioned. Formally speaking, a government's dynamic interactive capabilities represent the extent to which the change in its capabilities influences or is influenced by the change in the capabilities of policy 'suppliers' and users, all in real time.

Expressing such dynamic interactive capabilities in policy-making implies the need to operate through demand as well as supply factors, including the appropriate deployment of macroeconomic policy. In my paper in Revue d'Economie Industrielle I therefore argued that governments should move towards a 'Schumpeterian macroeconomics' (von Tunzelmann, 2004), involving the active use of macro demand expansion to encourage demand-pull innovation. I contended that in theoretical as well as practical terms this would overcome the shackle of a vertical aggregate supply curve as argued by monetarist economists.

To achieve this outcome implies in addition a need to enhance interactivity. In recent times this has led policy-makers to advocate approaches that involve support for 'clusters' – a view promoted further by the influence of advisers such as Michael Porter (Porter and Ketels, 2003). While these can help with the interactive side of the coin, they can be a sometimes hindering element as regards the pressure to act dynamically, since the notion of a cluster is inherently static. The dynamic counterpart of the cluster is indicated by the concept of a 'regional system of innovation', designed to promote interactivity for change occurring in 'real time'. Unfortunately the Regional Development Agencies (RDAs) set up to divide the country with this in mind in 1999 have lacked an adequate knowledge base for effective policy-making (Barber and Georghiou, forthcoming).

The key issue comes back to a need to 'align' the objectives of all types of actors and agents. In other words, I am claiming that the underlying source of policy inadequacy remains a matter of 'network failure' through misalignments. There is a need at governmental level to 'align' the micro, meso and macro levels, which may involve positive interactions between as well as within local, regional, national and global systems of innovation. There is an associated need – as the defensible but underwhelming resort to RDAs shows – to inculcate policy capabilities to make the desired connections, through 'policy learning' (both internally within each government organization, and externally through interacting with experts, evaluators, etc.).

4.6 Conclusions

The UK White Paper of 1988 (Cmnd 278) ended most support for single-company R&D and placed its emphasis on collaborative R&D, yet the underpinning economic analysis retreated deeper into the mystique of 'market failure'.

While it is sometimes possible to impute market-related costs to the fundamental shortcomings of policy-making noted in this paper, this does not mean that providing a market would have resolved the problem identified. Often, indeed, it might have exacerbated it, as with recent financial problems, or with the 'market for corporate control' (through encouraging myopic behaviour).

Instead, the paper sees the basic failings as being network failures in inadequate collaboration, and 'inter-systemic' failures of breakdowns between national 'systems' of science, industrial innovation, finance, workplace organization, etc. (von Tunzelmann, 2003) – in other words, alignment failures. These breakdowns in turn gave rise to a 'blame culture' from mutual misunderstandings, for example as between the 'separate spheres' of finance and manufacturing industry. The resort to middlemen consultants did little, in that such people were not trusted by SMEs (Barber and Georghiou, forthcoming). Meanwhile, the rather incongruous adherence to the 'linear model' involved a reliance on academic spin-offs for generating new technologies and also their diffusion. The split of the old DTI into the newly created departments called DIUS (for science and long-term technology development) and BERR (for business innovation) in 2007, if anything, looks likely to perpetuate the inter-systemic failures that have characterised British technological development for over a century.

In this chapter we have thus argued firstly that an analysis of technology trends indicates that non-market failures, mainly systemic and dynamic in nature, were a more basic source of British technological shortcomings than market failures. Secondly, an analysis of trends in UK technology policy has suggested that narrowly economics-based views too often hampered good intentions to reform policy along more appropriate lines, and restricted development of any serious capabilities for 'policy learning' in relation to innovation by UK governments both national and regional. While no country probably gets all the relevant networks fully aligned to achieve optimal output, the argument here is that the UK could gain from adopting 'better practice' approaches to improve its innovative performance.

We conclude that 'market failure' is at best a gross simplification of the issues confronting British technology policy in this era, and often an obstacle in the way of promoting and applying more constructive network-oriented policies.

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Chapter 5: Denmark

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5.1 Introduction

The integration of the Danish economy into global innovation networks can be explained partly by the features characterizing the Danish industrial sector and partly by the Danish innovation (and other related) policies. The globalization of the Danish economy has a long history and has gone through a number of processes some of which still prevail, namely: the increased international trade, the outsourcing and off-shoring of production to low cost areas, and most recently the increased international collaboration in innovation and R&D. Three features characterize the Danish industrial sector. First, a large number of small and medium sized enterprises (SMEs) and a relative low number of large firms. Second, Denmark specializes in low to medium tech industry characterized by incremental innovation. Third, Denmark has a high export ratio and a considerable degree of internationalization in virtually all sectors of the economy. This chapter aims at investigating Danish participation in innovation networks, and the degree of internationalisation of innovation related to the Danish economy.

An overview of the Danish industry sector. Danish industry is traditionally specialized in low-tech production. Some of the strong industries are food and beverage, furniture and, textiles; which typically engage in incremental innovations. But there are also strong international specialized and niche players among the large-scale companies, especially within pharmaceuticals, bio-tech, transport and electronics. This odd combination of actors with very different needs sets high demands for the national innovation system. Still, a large share of the Danish innovations takes place in SMEs. This can be explained by two factors: 1) policies have aimed at supporting SMEs and 2) they are strong in terms of networking. Although the home market is small it consists of relatively high-end consumers. In terms of innovation, the low and medium-tech specialization of the Danish economy has resulted in a relatively small ratio of radical innovations, and in the predominance of incremental innovation essentially of process and organization. Hence, innovation in Danish companies is characterized by 'Learning by doing' and 'Learning by interacting' (Christensen et al., 2008; Iversen, 2008; Benito et al., 2002). For this reason Denmark has also been termed 'artisanal innovation system' (Whitley 2006).

As mentioned above, the Danish business sector is characterized by a high degree of internationalization and export-oriented production structures (Iversen, 2008). This is as much the case for large firms, as it is for SMEs. It is worth noting that among the large scale companies, the export ratio is more than 50 percent which has created '…a complete new league of large globalized corporations' (Iversen, 2008: 12). This, the strong export-oriented nature and the fact that Denmark is an open economy, can be explained by the small size of the home market (Katzenstein, 1985). According to Katzenstein (1985) small economies depend on internationalization to obtain continuous growth and sustain their competitiveness. Hence there is a tendency for small economies to be more globalized than larger ones. Summing up, the Danish business sector is traditionally very strong organizationally in terms of formal as well as informal networks; and in innovation in terms of incremental process and organizational innovations.

The Danish political system. According to the literature of ‘Varieties of Capitalism’, the Danish political economy combines features of the ideal-types of Liberal Market Economies (LME) and Coordinated Market Economies (CMEs) (Hall and Soskice 2001). In other words, Denmark is a peculiar hybrid of these two ideal-types (Campbell and Pedersen 2007). The economy is characterized by a strong welfare state, which was developed historically under the influence of the social democrats, and in which business, politicians and unions work closely together in corporatist arrangements. This seemingly coordinated market economy is combined with a long established tradition of liberal market regulations. An emblematic example of this is the ‘flexicurity’ model of labour market, combining the flexibility of firing and hiring employees with generous publicly supported unemployment benefits.

Besides the formal institutions, the Danish economy builds on multiple informal institutions and social networks, exhibiting high levels of trust. For that reason it has been characterized as a ‘Village economy’. This notion of the Danish economy signifies the importance of strong personal networks and ties between different local actors (Maskell, 2004; Hall and Soskice 2001; Campbell and Pedersen, 2007). Danish companies relate to each other and to the political system by formal contracts and by multiple informal networks and collaborations.

Currently, the two characteristics (small open economy and liberal-coordinated welfare state) are under pressure due to economic globalization: a small open economy in an international division of labour, and the dominance of neo-liberal policies challenging the corporatist welfare state. ‘Globalization’ here refers to the transformation of companies and countries’ identities (through outsourcing, off shoring, access to international capital and economic integration); while ‘internationalization’ is understood as a process of opening markets (e.g. via trade).

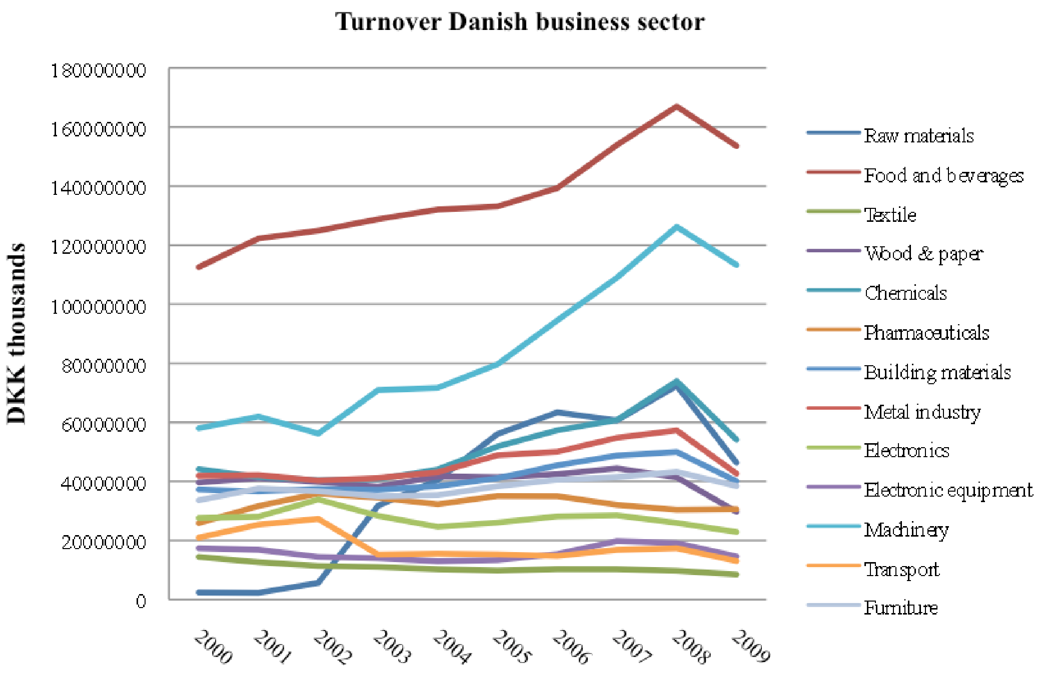
According to a study by Benito et al. (2002), which compared the ten largest companies in Denmark, Norway and Sweden, Danish large companies were more globalized and their share of international activities had grown considerably since the beginning of the 1990s. Another study of the large corporations by Meyer (2006) showed that large Danish companies globalize by developing into ‘global specialists’ within different niches. So far little is known about the extent to which innovation is related to and included in the global orientation of the Danish economy. This is the aim of this chapter.

Internationalisation of Danish industry. A joint report from 2008 by the statistical agencies of the Nordic countries showed that 52 percent of Danish companies with more than 50 employees practiced some international sourcing. Compared to the other countries in this report, Danish companies were more globally oriented in their sourcing. For manufacturing, 51 percent of the international sourcing came from EU countries and 49 percent from the rest of the world (of which 21 percent is from China), in services only 46 percent of sourcing were within the EU and 54 percent from the rest of the world (Denmarks Statistics et al., 2008). Furthermore, this report showed that Danish companies to a higher extent than companies from the other Nordic countries outsourced to enterprises outside the company group. Finally, the report showed that 13 percent of the companies, which were engaged with international sourcing, used ‘Access to specialized knowledge/technologies’ as their motivation factor for outsourcing (Danmarks Statistik et al., 2006: 54). In other words, Danish industry seems to be well established in networks – not only national but also international networks as well.

5.2 Background

Denmark has traditionally developed from being an agrarian economy; which developed further into an agro-industrial society during the period of industrialization, mainly through the introduction of standardized products and quality requirements. Innovation was within process and processing, and machinery. Combined with the overall geographical proximity, this led to some important common strains of innovation, through spillovers and spinoffs. One such strain of innovation (or national innovation cluster) emerged from the pork specialization (Danish bacon). As the production of pork increased and developed into a core export industry, it also had spin-offs into the development of: 1) a Danish pharmaceutical industry specialized in production of insulin, and 2) the refrigerator industry (cold chain related). Today, the main slaughterhouse, the cooperative Danish Crown, has remained one of the largest Danish companies and generates 87 percent (approx. DKK 47,000) of its turnover outside Denmark. Danish Crown has developed into an innovative company with innovation within e.g. robotics. These are developed in collaborations with Japanese companies.

Figure 5.1: *Turnover Danish Business Sector*.



Source: Danmarks Statistikbank (accessed 20 May 2010)

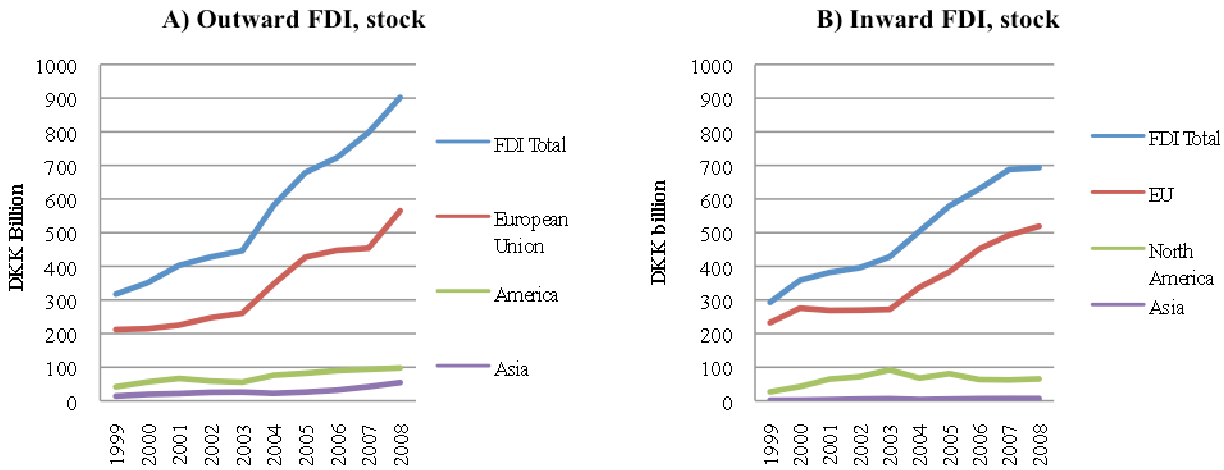
The Danish economy is to a certain extent still based on agro-related and agro-processing industries. Agro-related products accounted for 15 of Danish export in 2004. Other strong industries are furniture, design, agro food, biotech and pharmaceuticals. Figure 5.1 shows the turnover of the industrial sectors between 2000 and 2009. The figure clearly illustrates that the food/beverage/tobacco and machinery industries remain core industries in the economy.

From a globalization perspective, Danish enterprises increasingly engage in foreign investments and vice-versa. Figure 5.2 shows outward and inward stock of FDI from/to Denmark between 1999 and 2008. In particular the increase in outward investments supports the argument that businesses from small open economies engage in interactions outside their home country. It is also clear that EU is the main destination for Danish FDI, and that Asia as destination has increased slightly while the US' share has somehow stagnated. Figure 5.3 provides a clear picture of the role of Europe as a destination for outward FDI.

5.3 The institutional arrangements of the Danish innovation system

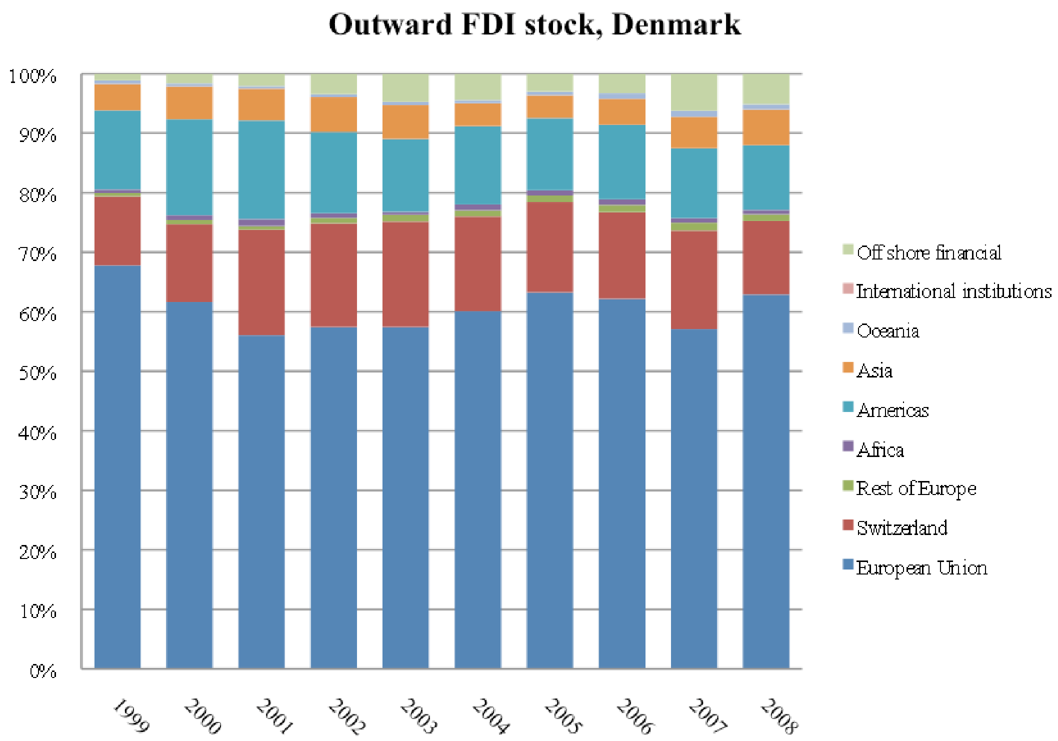
Innovation policies in Denmark are split between the Ministry of Science, Technology and Innovation (MSTI) and the Ministry of Economic and Business Affairs. The main tasks of MSTI in regard to innovation are to develop and implement instruments for the promotion of innovation in institutions and industry. MSTI is responsible for research policy, innovation policy, IT and telecommunication,

Figure 5.2: *Foreign direct investment stocks (cumulative), Denmark, DKK billion.*



Source: Danmarks Statistik 2009

Figure 5.3. *Danish investment abroad by destination.*



.*Source:* Statistics Denmark 2009

and the universities and related policies. Its role has increased notably during the past few years into almost a 'super-ministry' (Koch, 2008). One of the core ideas behind assembling these tasks under one umbrella ministry was to build bridges between knowledge centres, educational institutions, and business (Park and Lee, 2005). In addition to MSTI, the Ministry of Economic and Business Affairs also handles policy areas related to innovation. These are the incubator program, regional innovation networks, and business. The political requirements from the high tech industries are taken care of in MSTI while the low-tech industries are primarily under the Ministry of Economic and Business Affairs.

Under each of the Ministries there are several councils and agencies with different responsibilities for innovation and research. Some of these are the Danish Agency for Science, Technology and Innovation, the Council for Strategic Research providing research grants; there is also a fund for 'high-tech' established in 2005 to strengthen the competitiveness of Denmark within high-tech industries. Furthermore, Denmark is divided into 5 regions which each has different regional initiatives regarding innovation, e.g. the development of 'hubs' such as a 'Medicon Valley' and an 'Agro Food Science Park'.

The Danish innovation policy has been going through changes in order to facilitate more networking activities. Public funding or public procurement has facilitated (and is still linked to) much of the high-tech knowledge intensive and innovative industries. Two often-used examples are the wind turbine industry and the industry for hearing aids (Christensen et al., 2008). For both these, Danish companies have developed into global technology leaders.

Education and innovation. Although innovation policy became centralized in the MSTI lots of policies outside this ministry have a direct impact on companies innovativeness. One example is policies regarding education. Denmark has developed into a knowledge-based economy in which knowledge is generating by doing, using and interacting (DUI). This is basically facilitated by the mode of teaching in the Danish school system. Government at the local and central levels provides a free of charge educational system, both at the primary, secondary and tertiary level. The public school system is widely used, and private schools primarily constitute primary schools. Private high schools are even less common.

All tertiary education institutions in Denmark are public and free of charge. The tertiary educational system has undergone some recently restructuring in which the universities have been merged and centralized, and most important here, universities are now explicitly required to engage with the private sector, e.g. in innovation networks and through technology transfer. However, there is a lack of students going into science education (Christensen et al. 2008), and the share of Danes enrolled in science and technology degrees is at the EU27 average. Throughout the tertiary studies students get a monthly allowance from the state supplemented by access to state guaranteed loans with low interest rates. This system includes not only university but also students in vocational training.

The curricula taught generally support communicative and cooperative learning and development of 'social competences'. The Danish educational system aims at a high degree of equality through open access and support to individual students. Therefore, the pedagogical emphasis on learning by doing, problem-oriented project work, and communication, as well as the free and accessible system for all, characterizes the Danish system as a truly 'learning society and economy' (Lundvall and Johnson 1994). Besides the formal education system many participate in vocational training, 27.6 of 25 - 64 year olds attended some training activities in 2005 (EU average 11).

Incurbator and regional innovation. In relation to business, the 'Incubator initiative' supports entrepreneurs, e.g. by providing venture capital from investment and pension funds. The engagement of pension funds leads to increased availability of long-term investments for promising companies. Likewise, a state backed investment company (Vækstfonden) was established to assist companies financially in bringing their inventions to commercial markets. Together these provide good possibilities for supporting innovation initiatives at early stages and in long time perspectives. However, both initiatives primarily support high-tech oriented SMEs. Also the Regional Innovation Centers have funding for supporting entrepreneurs and establishing innovation network facilities. Furthermore, there is a system of technical service in 'Approved Technological Service' (GTS, Godkendte Teknologiske Serviceinstitutter). SMEs receive a financial subsidy for their first-time use of one of the GTS institutes (Christensen 2008). The 2007-2010 government Innovation Strategy included funding for establishing 20-30 networks including approx. 1000 companies. Additionally there are programs for public funding for companies participating in international innovation consortia.

By 2008, MSTI had established 27 innovation networks consisting of companies, regional centres for technology, universities, and GTS. These networks focus on specific areas such as pharmaceuticals, biotech, agriculture, robotics, IT, renewable energy and health. By 2008, 345 companies had, according to the ministry, developed new products, services or process from collaborations in the networks. The initiative is supported by approx. DKK 1 billion per year (Forsknings- og Innovationsstyrelsen, 2008). In addition to the formal networks, there are a number of networks formed through strong informal institutions. As mentioned in the introduction, Denmark is a network society, a 'village economy', and the innovation policies are also built to support, strengthen and develop existing network structures.

5.4 Main organizational actors in the innovation system

Table 5.1 shows that 40.8 percent of the Danish SMEs have in-house innovation activities (against 30.0 percent in the EU27) and 14.9 percent of the Danish SMEs (against an EU27 average of 9.5 percent) were involved in innovation co-operation (slightly lower than in 2004 where Danish SMEs had 15.8 percent co-operation against the EU25 level of 7.1 percent) (Commission of the European Communities, 2004, 2009). There seems to be a high degree of co-operation between SMEs. It is also worth mentioning that the number of employees with a tertiary education is considerable higher in Denmark than EU27 average. Finally, the table shows that employment in high-tech in Denmark is lower than in the EU27 countries.

Table 5.1. *Innovation Scoreboard indicators 'Enablers' for Denmark and EU27*

Enabler	EU27	Denmark
Tertiary education (per 100 pop aged 25-64)	24.3	34.5
Life-long learning (enrolled per 100 pop aged 25-64)	9.6	30.2
SMEs innovating in-house	30.0	40.8
Innovative SMEs collaborating with others	9.5	14.9
Employment in medium-high and high-tech manufacturing	6.59	5.83

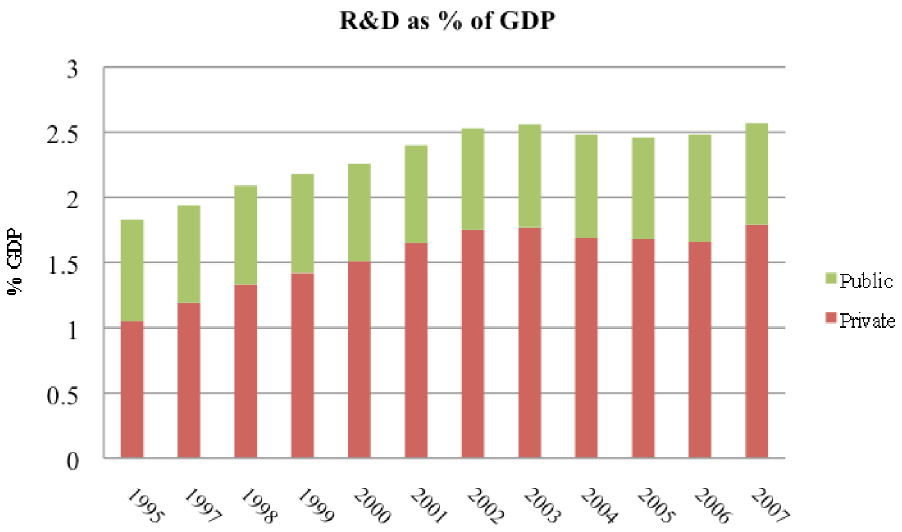
Source: European Innovation Scoreboard, Commission of the European Communities 2009.

Research and development (R&D) expenditure has grown considerably in Denmark over the last 15 years. Figure 5.3 illustrates that it has increased from 1.83 percent of GDP in 1995 to almost 3 percent in 2008. Private companies are the main contributors. Currently the private sector contributes with two thirds of the total R&D expenditure. Public funding has remained just below 1 percent of GDP over the period. Employment within R&D in number of employees has increased from 67,267 people in 2005 to 84,277 in 2008, of which 31,724 are employed in the public sector and 52,646 in the private sector.

Figure 5.4 splits the business' contribution to R&D into the size of the companies. It shows that the large companies contribute with the highest level of funding. However, the same figure also shows that the SMEs finance a considerable share as well. Less than 1 percent of the companies have more than 1000 employees (Nordisk Ministerråd 2005). Therefore there is a need for government supported initiatives facilitating collaboration and co-operation between companies, research institutions and universities in Denmark (Park and Lee, 2005) and increasingly abroad.

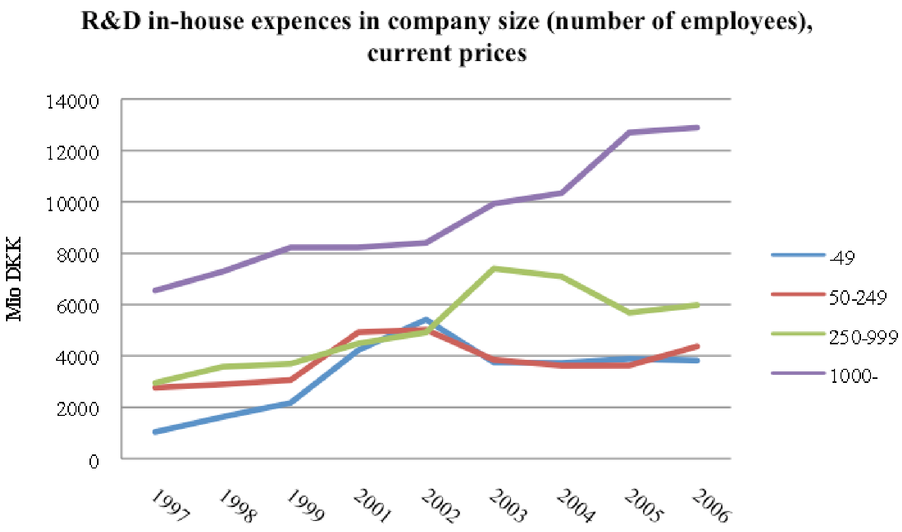
If the business' contribution to R&D is divided into the level of technology (Figure 5) the companies are engaged in, the high-tech companies invest the lion's share. This does not necessarily imply that SMEs are not innovative. In a large project researching innovation in Denmark – DISKO – carried out in the early 1990s (Lundvall, 1999), the Danish business sector was found to be a landscape of small islands of high tech and an ocean of low tech companies conducting process and

Figure 5.3 *R&D spending in percent of GDP*



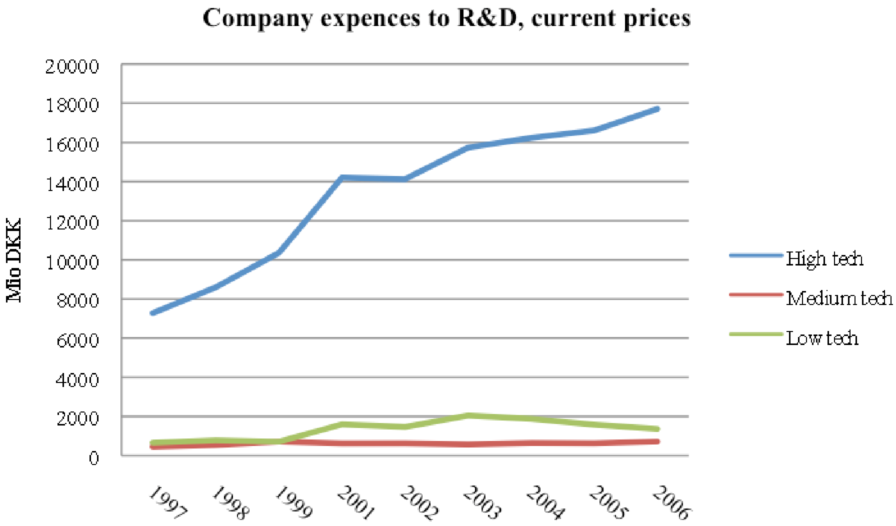
Source: Danmarks Statistik 2008.

Figure 5.4. *R&D expenditure by size of companies*



Source: Statistics Denmark 2007.

Figure 5.5. *R&D according to the level of technology*



Source: Statistics Denmark 2007.

organizational types of innovation (Lundvall, 1999). However, although food and beverages are 'low tech' and have relatively small R&D budgets, they need very sophisticated competences and industrial designs.

Despite of this, the overall science and technology profile of Denmark is strongest within medium- and low-tech manufacturing. The core competences are within ecology/environment, plant and animal sciences, immunology, agricultural sciences, astrophysics, biology and biochemistry, molecular biology and genetics, and clinical medicine, organised in regional innovation hubs such as: Medicon Valley Copenhagen, Mobilecom in Aalborg, Textile in Herning, and food and packaging along with the food and beverage industry (Edquist and Hommen, 2008).

Some of the other core characteristics of the Danish economy are: frequent flux of personnel between companies and universities due to the flexicurity welfare system. The fact that state, business and specialized unions coordinate the economy has led to a system of 'flexicurity'. Flexicurity ensures that skilled workers are flexible as unemployment benefits are relatively high which result in high mobility at all levels. Furthermore, it is easy to hire and fire. Accordingly there is a tendency at all levels that employees change jobs relatively often. The unemployed are generally enrolled in a continuous process of upgrading their competencies through active labour policies with public programs offering vocational training. This has also been termed 'life-long learning', as workers re-train their skills adapting to new labour market needs. This system requires both social benefits during unemployment periods and a pro-active public sector facilitating and supporting the creation of vocational training courses. In relation to this there is a high mobility between jobs which makes it necessary for the public sector to provide these types of competence building as private firms are in investing in education due to the risk of losing their 'investment' - i.e. lack of incentives (ibid.).

5.5 Competencies and capabilities

The Danish industry is specialized in products containing relatively little science and research, however the industry is innovative as it is specialized in global market niches (Christensen et al. 2008) and it has good capabilities to absorb knowledge and technology developed outside the country (Lundvall, 1999). This underlines Danish companies' need to engage with global networks. Many companies have developed strong collaborations with suppliers and customers (see also table 5.4). This is also a characteristic for incremental innovation, namely that up- or down-stream partners assist in adjusting the products, i.e. through incremental innovations. Table 5.2 shows that Danish enterprises have a high level of R&D spending relative to the EU27.

Table 5.3 shows the share of manufacturing companies who experience innovation in the period 2004-2006. The industry is relatively low-tech: "Denmark's so-called low- and medium-tech production is based upon extensive knowledge inputs related to a high degree of change and flexibility in firms' use of resources, including rapid diffusion of new technologies and frequent incremental product innovation combining a high level of competence in industrial design with advanced organizational techniques and marketing methods" (Christensen et al., 2008: 406). Design is also knowledge intensive – the creative industries account for 16 of DK's export.

According to CIS3 and other surveys, Danish firms are only innovative to a limited extent. The companies' explanations to this are: 'market conditions', 'not necessary due to earlier innovations', 'lack of resources', 'lack of time' (Christensen et al. 2008; Christensen 2004). For the firms engaged in innovation, these are successful in 'new to the firm' innovations. Only 11 percent of the Danish companies create original innovations – processes and products, which are new to the world. Another 29 percent create innovations, which are new to the sector. Sixteen percent of the companies claim to innovate at a level, which brings about economic results (ibid.). Danish companies are 'Learning organisations' which account for 60 percent of employment (against EU-15 average 40) (Christensen et al., 2008). This can be explained by the egalitarian system described above.

Looking into the extent of collaboration and who Danish companies collaborate with others in regard to innovation, Table 5.4 shows (in the first 3 columns) the share of companies who collaborated with external actors from 2000 to 2006. As the table shows, collaboration activities were declining over the period, contrary to what we would have expected, i.e. that globalization would lead to the opposite. The columns on the right show with whom the companies collaborated in the last period (2004-2006). Here it is shown that users/customers and suppliers were their most important innovation partners.

Table 5.2. *Companies R&D spending as percentage of GDP,*

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Denmark	1.18	1.32	1.41	1.50	1.64	1.73	1.78	1.69	1.67	1.65
EU27	1.04	1.04	1.10	1.11	1.12	1.12	1.11	1.09	1.09	1.11

Source: Danmarks Statistik Erhvervslivets Forskning og udvikling 2006

Table 5.3: *Share of Danish companies engaged in innovation 2004-2006 (percentage according to size and type)*

		Innovation type					
		Product	*Process*	*Product and/or process*	*Organis-ational*	*Marketing*	*Any one of 4 types*
Company type*	High tech	40	39	52	40	42	66
	Medium tech	20	32	36	29	25	43
	Low tech	23	25	37	33	40	53
Company size	2-9	24	29	37	32	39	51
	10-49	22	26	33	34	33	48
	50-249	27	32	42	49	40	64
	250-999	48	43	57	62	46	77
	1000 -	54	58	66	75	61	90

Note: The three company types are within 'manufacturing'
Source: Danmarks Statistik 2006b

CIS3 also shows that Danish companies preferred collaboration downstream with their clients and customers (90 of innovative companies). DK customers have high per capita income and therefore high degree of buyer sophistication, which has been argued to 'influence the propensity to innovate positively' (Christensen, 2008: 414). On top of that, some sectors are driven innovation wise by public procurement and public incentives – two commonly used examples are wind turbines (tax incentives and public research centre in RISØ; knowledge sharing in industrial associations) and hearing aids (public support for people in need of hearing aid, Danish Technical University, 3 out of 6 global lead-firms are Danish).

Regarding intellectual property rights, here patents, Denmark is a country with traditionally low patenting ratio when compared to other Nordic countries, particularly Sweden and Finland. This is largely associated to the incremental type of innovation performed by SMEs, as mentioned above. However, interestingly enough, the value of those patents seems to be higher than in other countries. A 2006 research project from Syddansk Universitet shows that patents granted to Danish companies in

Table 5.4: *Companies engaged with innovation co-operation*

		2000-2002	2002	2004-2006	*Cooperation partner* Users/ cutomers	Market	Consul-tancies (incl. GTS)	Suppliers	Public Institut-ions
*Company type**	High tech	61	50	39	19	10	11	18	18
	Medium tech	41	38	28	18	6	11	16	9
	Low tech	53	28	34	26	9	12	19	7
Company size	2-9	56	50	41	25	9	10	25	13
	10-49	50	41	31	18	10	7	19	10
	50-249	55	44	38	22	10	11	23	11
	250-999	67	64	55	32	16	16	38	17
	1000 -	77	67	55	31	28	19	37	26

Source: Danmarks Statistik 2006b

the period 1978 and 2003 had higher value than those granted to companies in UK, Germany, Spain, Italy, The Netherlands, and France. In Denmark 67.9 percent of patents are under commercially use in contrast to only 54.5 percent in the other six European countries. For example, in the large and highly innovative Danish companies such as Novo Nordisk, Danfoss, Haldor Topsøe and Velux, 25 percent of their patents have a market value of more than 10 million Euros. For smaller companies' patents the share is 11.7 percent. However, this is still above the other EU6 companies' 7.2 percent.

As mentioned earlier, Danish companies are very much oriented towards Europe in their internationalization strategies. In 2008, Danish companies had a total of 8,423 subsidiaries. 87 percent of these were located within Europe, followed by Asia (10 percent), North America (7 percent) and the rest of the world (7 percent) (Statistics Denmark 2008).

Looking at companies sourcing R&D, Table 5.5 shows the number of companies reporting sourcing of R&D in 2006 the type of partners, and whether it was sourced from Danish partners or from abroad. The table shows that companies tend to buy R&D from abroad, especially high-tech and large companies. When calculated together, Danish companies source more from abroad (DKK 4,385 million) than from Denmark (DKK 3,500), which indicates some engagement from Danish, enterprises in international innovation networks. (Danmarks Statistik 2006).

5.6 Global knowledge flows

Table 5.5: *Danish companies’ R&D sourcing 2006.*

		Companies buying R&D	Bought in Denmark (DKK mio.)			From abroad (DKK mio.)		
			From companies in the same concern	Other companies	Public institut-ions	Foreign companies in the same concern	Other companies	Public institut-ions
Type of company	High tech	322	171	651	132	1013	2422	58
	Med tech	88	4	25	6	52	2	1
	Low tech	188	145	71	78	41	13	7
Company size	0-49	962	410	551	140	64	561	17
	50-249	348	274	214	219	386	149	21
	250-999	106	248	276	78	380	124	10
	1000-	33	223	804	63	705	1936	32

Note: Company size based on employees
Source: Danmarks Statistik Erhvervslivets Forskning og udvikling 2006

Table 5.6 *Percentage of intramural R&D financed abroad by number of persons, 2003 and 2005.*

	Percentage share of intramural R&D financed abroad		*Percentage of total intramural R&D financed abroad*	
	2003	2005	2003	2005
Total in million DKK	2.997	2.956	…	...
Persons employed				
Total	100	100	12	11,4
1 to 9	1	0,8	2,8	3,4
10 to 49	5,6	6,5	6,3	6
50 to 249	13,6	11,6	10,6	9,4
250 to 499	6,7	1,6	6,5	2,1
500 to 999	24,1	22,7	16,7	19,6
1000 and more	49	56,8	14,8	13,2

Source: Statistics Dansk Center for Forskningsanalyse

Table 5.6 shows how much of the intramural R&D in Danish companies is financed abroad (by number of people engaged in Danish industry). This shows a small decrease among the medium sized companies while small and large companies’ R&D financed abroad has increased. According to this table, large companies are by far the most internationalized in terms of R&D activities.

Looking into extramural international R&D sourcing, i.e. to which countries Danish companies outsource different activities it seems that sourcing of R&D are more globalized than their sourcing of other activities. A survey carried out by the Ministry of Economic and

Business Affairs (2008) showed that among 3,145 companies participating in the survey, 94 companies (2.7 percent) engaged in international sourcing of R&D in the period from 2001 to 2006. 19 percent of the companies involved in the survey outsourced one or more functions in this period. Table 5.7 shows the activities outsourced by the 19 percent sourcing from abroad. Although only 2.7 percent of all the companies carried out R&D outsourcing is the most widely globally distributed activity of Danish companies' outsourcing activities. In particular India and China stand out as important locations for R&D outsourcing.

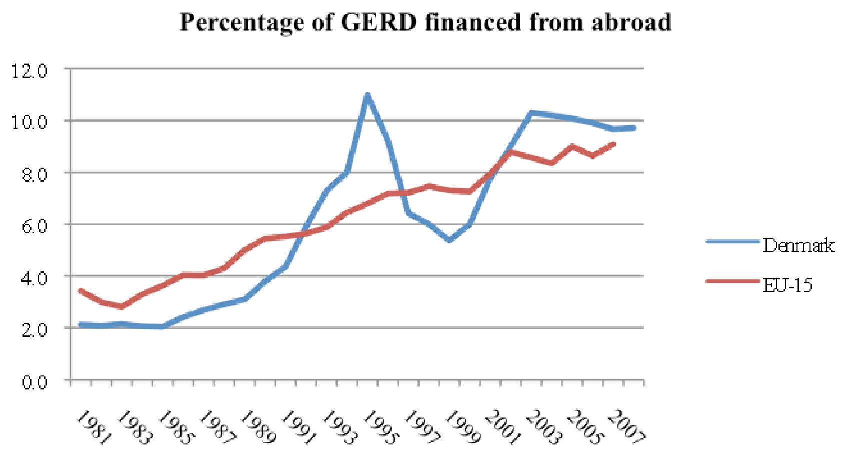
R&D outsourcing and investments also take place in the other direction. Foreign companies increasingly locate R&D facilities in Denmark. This can be seen in Figure 5.6, which also shows that the percentage of GERD (Gross Expenditure in R&D) financed from abroad in Denmark correlates with the EU15 average. Foreign companies investing in Denmark can receive advice and support free of charge from Danish agencies such as 'Invest in Denmark' and 'Copenhagen Capacity'.A recent example is the decision made by the Chinese Genetech company BGI China to establish a research centre in Copenhagen.

Table 5.7: *Geographical distribution of Danish companies' planned outsourcing activities 2007-2009, by activity.*

	Core activ.	IT	R&D	Market-ing	Distrib.	Admin.	Engineering	Other	Total
Europe	53	63	46	53	60	65	51	47	55
China	22	7	13	18	18	10	19	27	16
India	9	18	26	12	5	12	19	7	14
Rest of Asia	8	7	8	8	8	5	7	16	8
North Am.	4	3	6	5	4	4	3	4	4
Rest of Am.	3	1	1	2	5	2	0	0	2
Africa	0	1	1	2	0	1	0	0	1
Total	100	100	100	100	100	100	100	100	100

Source: Økonomi og Erhvervsministeriet 2008.

Figure 5.6: *Share of GERD financed from abroad.*



Source: OECD MSTI Database, 2009.

According to Christensen (2008) Denmark is lagging behind Europe in entrepreneurship and there is a 'widening gap between Denmark and the rest of the world' (Christensen 2008: 418). The argument here is contrary the flexibility system as it is argued that social benefits for unemployed leads to a situation where 'entrepreneurial activities simply motivated by lack of other income possibilities are low' (ibid.). Moreover, innovation in Danish companies are also characterized by intrapreneurship, i.e. most organizations are learning organizations and provide employees the opportunities in place in their existing workspace.

5.7 Concluding remarks

The relations between the Danish economy and global innovation networks are very much based on the level of which companies themselves engage with external actors, also in other countries. However, being a small open economy requires both global out-reach, internal openness and continuous upgrading of the labour force through vocational training. A result of this is that the business share of GERD is relatively high and Danish employees attend lifelong learning at a higher degree than most other countries. Likewise, the share of people with a tertiary education is higher, thus not in engineering and science. The dominant industries are within low- and medium-tech engaged primarily with incremental innovation predominantly in collaboration with customers. In addition to this, there are the relatively larger high-tech companies, which have a high return on patents. Still, cooperation in innovation decreased in the period from 2002 to 2006. At the political level, regional innovation clusters and networks are facilitated by government initiatives and support schemes. This is primarily to support small and medium scale corporations and/or specific industries. In order to streamline innovation policy, Denmark has been through a process of centralization of innovation and science under the Ministry of Science, Technology and Innovation.

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Chapter 6: Norway

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6.1 Introduction

Norway is a small open economy, with just over 4.6 million inhabitants, that relies heavily on a sophisticated exploitation of several significant natural resources. Wicken (2008) identified three different layers within the Norwegian innovation system: one with small scale enterprises operating with little knowledge accumulation, one with large scale enterprises that are knowledge intensive and rely on collaborative learning, and one with small R&D intensive enterprises that rely on collaborative learning with other enterprises and research organizations and likely to operate within global innovation networks. This diversity intersects with a specific economic specialization that is related to natural resources. In this Chapter we argue that economic growth in Norway is based on knowledge intensive production processes within low and medium-low technology industries, such as gas and oil extraction, marine and maritime activities, metals, etc. We show that the country's economic structure, its research and innovation system and its knowledge networks exhibit consistent patterns.

The chapter contains seven sections. In the following section the economic performance of Norway and the economic environment for innovation in Norway is presented in some detail. The third section sketches out the governance of the Norwegian innovation system in the context of a globalizing research system. Section four describes the main actors in the Norwegian innovation system, focusing on foreign sources of finance for R&D activity and R&D activity performed abroad by Norwegian enterprises. The fifth section investigates the international orientation of the Norwegian Innovation System, focusing on the R&D activities of foreign multinationals and R&D activity performed abroad by Norwegian enterprises. Section 6 analyzes the knowledge flows and global networks in the Norwegian innovation system. A final section sums up the analysis in terms of the emergence of global innovation networks.

6.2 Economic performance and the economic environment for innovation

Norway was a relatively poor country in the European context. Labour productivity, measured in terms of per capita income in Geary-Khamis dollars, was only 89 percent of the Western European average and 65 percent of the United Kingdom average in 1820 (Maddison, 2006). By 1870 it had fallen to the 69 percent of the income of the average European and 45 percent of the average income in the United Kingdom. Very little progress was made up until 1913, but by 1950 Norway had already surpassed the European average and narrowed the productivity gap with the United Kingdom to only 79 percent in that year. In 2009 it had one of the highest rates of productivity in Europe, even when measured in Geary-Khamis dollars or output per hour, according to the Conference Board Total Economy Database.

Over the past decade, the economic performance of Norway was consistently strong with high productivity growth, low unemployment, low inflation, high wealth creation and large surpluses in the balance of payments. A strong contribution from the petroleum sector helped push the economy, with continuing high investments, but other sectors also performed very well, such as manufacturing and private and public services. And unlike many of the other European economies, Norway was shielded from any significant impact from the global financial crisis, experiencing only a mild downturn in 2009. A large public sector and an expansive fiscal policy helped reduce the potential impact of the financial crisis. Norway’s economic performance in terms of per capita GDP growth has been consistently high for a long time, and average real incomes are well above the average in the European Union. Norway has also recorded high productivity growth over the longer term. Between 1970 and 2005 labour productivity grew at an average rate of about 3 percent a year, in the same range as Finland and Japan (OECD, 2008).

Increasing labour productivity and a rising standard of living are closely tied to the ability to successfully introduce new or improved good or services into the market, or to successfully implement changes to the process of production or to the organization itself. Nevertheless, Norway displays patterns of very high labour productivity, but it appears in the European Innovation Scoreboard as a ‘moderate innovator’, with innovation performance and average annual growth in innovation well below the EU-27 average. The relative weak performance of the Norwegian innovation system, especially when measured relative to its GDP, has created a kind of “puzzle” that has caused considerable concern in the country (see Fagerberg, 2009). Koch and Hauknes (2007) provide four reasons that might explain this apparent puzzle: 1) There is a general over-emphasis on R&D-based indicators and on the impact that a high R&D-indicator performance has on economic growth; 2) Petroleum revenues generate more than 20 percent of GDP and, hence, a large part of economic growth, and of labour productivity, is linked to wealth from natural resources; 3) Norway does not have a large high-technology industry and therefore its R&D intensity is lower than ICT-producer countries; and because of that 4) R&D spending in Norway is not very different from that in the largest OECD, when adjusted for the industrial structure. They also point out that Norwegian companies in the low-technology industries tend to be more research-intensive and collaboration seeking than low-tech companies elsewhere and that the petroleum industry, traditionally believed to be a medium to low technology industry, also tends to be considerably more innovation-intensive than in many other oil producing countries. The latter is due to the fact that in Norway the oil and gas industry invests heavily in large infrastructure offshore projects demanding a highly sophisticated system of global and local knowledge networks of oil and gas suppliers and other technology providers. Such investments generate innovation activities, which cannot always be classified as R&D (as defined in the Frascati manual) and this opens for the possibility that in Norway – as well as in other advanced natural resource-based economies – there is a higher R&D driven innovation activity than what is reported in the official R&D-statistics. From this perspective the contribution of global networks of embodied technology providers, horizontal and vertical liaisons and research and innovation collaborators to the Norwegian wealth creation is higher than conventionally assumed.

For these reasons, the ongoing innovation policy debates in Norway reflect doubts that standard R&D and innovation indicators adequately capture the underlying innovation activities that sustain the strong Norwegian macroeconomic performance. Even when the petroleum revenues are excluded, productivity growth in the Norwegian economy remains very strong and many of the enterprises are generally considered to be knowledge-intensive, making extensive use of advanced knowledge, technology and machinery. Comparisons between Norwegian companies and companies in other European countries, business sector by business sector, indicate that the level of R&D investments in Norway are, when adjusted for industrial structure, higher than most of its competitors in several sectors. The new White Paper on Innovation has explicitly stated that standard indicators, rely on the standard definition of what is high-tech and that standard measures are too R&D-biased to adequately capture innovation performance in Norway.

A more comprehensive set of indicators capturing learning-by-doing, learning-by-using and learning-by-interacting activities in an economic system may provide a more accurate picture of the Norwegian innovation system's performance. As pointed out by Lundvall (2007) it is likely that non science-based economic sectors seem to rely more on learning activities underlying the innovation process, which may be are more apt to reveal the real significance of GINs in the Norwegian economy. It is for this reason that production networks within and between firms (doing, using and interaction networks), business networks (interactions defining and shaping players and business transactions in an industry), learning networks (learning-by-doing, learning-by-using and learning-by-interacting), and innovation networks (R&D or other knowledge based interactions) make up an important part of the Norwegian innovation system. These three types of networks could be seen as overlapping, but yet distinct forms of knowledge networks at local, national and global levels. Interactions and economic transactions in the economic system define the operational logic which shapes business opportunities within which networks becomes necessary to generate, use and diffuse new technical knowledge. It is in this way that the concept of global innovation networks, understood as intertwined and co-evolving international networks in research, business and production, becomes meaningful. This requires a better understanding of the specialization patterns of the Norwegian economy.

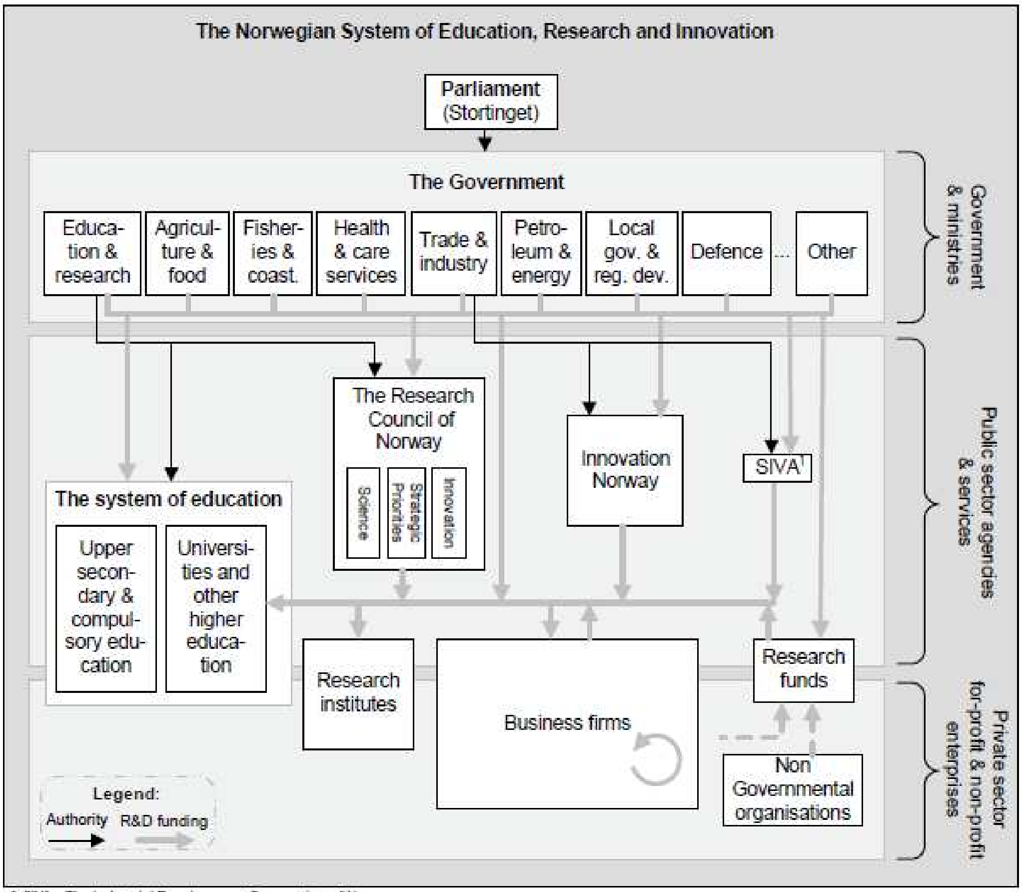
Kaloudis et al. (2006) describes the specialization patterns in Norway relative to the original 15 Member States of the EU. In terms of value added, Norway appears to be highly specialised in mining (mainly petroleum and gas extraction, NACE 11), shipbuilding (in particular, building and repairing oil platforms and modules, NACE 35.114) and transport (both transport via pipelines, NACE 60.30 and general water transport NACE 61). Norway exhibits also an increasing specialization in electricity, gas and water supply. This is the footprint of the petroleum cluster in the Norwegian economic system. In terms of employment, Norway appears to be specialized in shipbuilding and transport, in printing and publishing (NACE 21), Basic metals (NACE 27), Electricity, gas and water supply (NACE 40-41), Community Services (NACE 75-99), R&D services (NACE 73) and Telecom-services (NACE 64). As to R&D services, one should note that the bulk of non-profit industry-oriented research institutes in Norway are classified in this sector. The number of employees in the Norwegian research institute sector is high compared to many other EU-countries. This may explain why Norway does exhibit employment but not value added specialization in this sector.

6.3 The global orientation and governance of the Norwegian innovation system

Governance of the Norwegian Innovation system involves many different ministerial bodies, advisory structures and a range of different actors, all concerned with the making and steering of policy and its implementation. Figure 6.1 illustrates the Norwegian innovation governance system. The Norwegian Parliament (Storting) is the highest political authority for STI (Science, technology and innovation) policy in Norway. While there is no single forum focusing exclusively on STI policy issues, they are considered in several parliamentary committees, most directly in the Standing Committee on Education, Research and Church Affairs (Kirke-, utdannings- og forskningskomiteen); the Standing Committee on Business and Industry (Næringskomiteen); and the Standing Committee on Energy and Environment (Energi- og miljøkomiteen). Three ministries play a key role in the development of STI policy: (1) The Ministry of Trade and Industry (Nærings- og handelsdepartementet, NHD); (2) The Ministry of Education and Research (Kunnskapsdepartementet, KD); and (3) The Ministry of Local Government and Regional Development (Kommunal- og regionaldepartementet, KRD.

Several other ministries consider STI policy as important to their main agenda. The ministries for Agriculture and Food (LMB), Fisheries and Coastal Affairs (FKD) and Petroleum and Energy (OED) target innovation in private industry, and the ministries for Health and Care Services (HOD) and Government Administration and Reform (FAD) are important for innovation in the public sector. Coordination of sector innovation policies is the responsibility of the Ministry of Trade and Industry. The Ministry of Education and Research is responsible for coordinating R&D policies across ministries and across policy areas.

Figure 6.1: *The Norwegian Innovation governance system*



1 SIVA – The Industrial Development Corporation of Norway.

Source: NIFU STEP

Three agencies are entrusted to implement national STI policies: (1) The Research Council of Norway; (2) Innovation Norway; and (3) The Industrial Development Corporation of Norway. The Ministry of Education and Research administers the Research Council of Norway (RCN), and bears the overall responsibility for the promotion of basic and applied research within all scientific and technological areas. It is made up of two administrative divisions and three research divisions, including a separate division for innovation. RCN is also responsible for enhancing the participation of the Norwegian business sector in the EU Framework programmes for R&D.

Innovation Norway is the main agency for the development and administration of private sector-oriented policy instruments. Through its network of offices, covering all Norwegian counties and more than 30 foreign countries, the agency functions as a gateway to a well-coordinated and easily accessible set of policy instruments in the field of innovation and internationalisation of Norway based businesses. More specifically, Innovation Norway assists promising Norwegian SMEs with the promotion of their product and services to international markets, with legal and other technical knowhow in export and imports of services, IPR consultancy services, consultancy services on EU law and regulations, with identifying business partners in other countries (including USA, China, India and Japan).

The Industrial Development Corporation of Norway (SIVA) is a network organisation, which offers an infrastructure for entrepreneurship and innovation nationwide. It contributes to the development of strong regional and local industrial environments as co-owner of virtually all the science and research parks, incubators and business gardens in the country. Another agency, which plays a role in implementing innovation policies, is the Norwegian Design Council (NDC), which has the mandate to promote the use of design as a strategic tool for innovation by supporting Norwegian businesses’ understanding, knowledge and use of design. The active involvement and collaboration of social partners – labour, industry and government – is a key structural characteristic of the policy process in economic and industrial policy ('the Nordic model'), and these procedures apply in innovation policy as well. The Confederation of Norwegian Enterprise (NHO) is extensively involved in innovation policy processes and debates.

The first Norwegian White paper on innovation policy, titled, *An Innovative and Sustainable Norway* (White Paper No 7) was published in December 2008. It is the first comprehensive innovation policy document that a Norwegian government has published for discussion in the Norwegian Parliament. An earlier strategy document, published in 2003 by Norwegian Ministry of Trade and Industry, provided an action plan for the government to create a comprehensive innovation policy across ministerial boundaries, but it was not part of the parliamentary process. The 2008-2009 White Paper was developed within a very comprehensive process, through extensive consultations and meetings with stakeholders. It is based on a wide definition of innovation as 'a new commodity, a new service, a new production process, application or form of organisation, which is launched in the market or used in production to create economic value.'[9] The paper distinguishes invention from innovation, emphasising that an idea or invention does not become an innovation until it becomes a practical application. It is, hence, crucial to take into account all factors that may facilitate the transition from invention to innovation, including lack of critical resources, knowledge, international networks or complementary innovations.

Emphasis is placed on the pervasive character of innovation: 'Innovation takes place in all industries, in all types of enterprises and within all technologies'. This implies, inter alia that the White Paper positions itself in opposition to high-tech-biased conceptions of innovation, and indicates its sceptical view on 'measurements of innovation [that] tend to put the strongest emphasis on high-technology industries'. By emphasising the pervasive character of innovation, and, hence, the comprehensive scope of innovation policy, the paper indicates that it is important to enhance the focus of innovation policy on less technology-intensive activities, such as services, and in particular on innovation in the public sector. The White Paper adopts the concept of 'innovation systems', using it in a very wide sense to denote 'all framework conditions, structures and institutions which may have an influence on the volume of innovation and learning in enterprises'. Hence, the innovation system 'includes most policy areas, regulatory frameworks, public support of industry, social structures and support systems, research and teaching institutions, employees and leaders, customers, suppliers and market conditions and so on'.

A key objective of the present Norwegian innovation policy is to respond to the challenges of the increasingly globalised economy; international competition drives specialisation, innovation and change in the Norwegian economy, as in all other countries of the world. The

[9] Author’s translation. All citations are from pages 13 to 16.

White Paper frames the challenges and globalisation in terms that emphasise opportunities rather than threats, noting that 'Norwegian industries are well accustomed to international division of work, and to adapting to the effects of international competition'.

By strongly emphasising the global, cross-sectoral and systemic scope of innovation policy, the new policy agenda encompasses objectives in several policy areas. First, as part of the broader industrial and innovation policy framework, it includes a number of measures and programmes in support of innovative start-ups and entrepreneurship. These include innovation networks that provide infrastructures for innovative start-ups (science parks, knowledge parks, business gardens), and specific programmes, which provide direct support for such start-ups. A specific industry policy strategy for SMEs will also be developed and a separate strategic advisory council will be set up. And priority is given to the reduction of red tape for small enterprises.

Second, education and competence are defined as core areas of innovation policy. The White Paper emphasises the role and potential for improvement in education and competence building at all levels, from primary education to higher education, including vocational education and training and lifelong learning. It emphasises in particular that education must be relevant for work, and sees unmet needs and unexploited opportunities for enhancing collaboration between education institutions and enterprises. Learning at work and the role of continuing education and training in that connection are consequently strongly emphasised. The role of entrepreneurship in education is also emphasised, in particular in higher education.

Third, in recognition of the strong dependence of national private R&D-activity on economic structure, Norway no longer subscribes to its previous literal adoption from 2005 of the Barcelona target and it is stated that both the public and private components of the 3 percent target are now only targets to be reached in the unspecified 'long term'. This strategy also shifts focus toward the regional dimension. Fourth, as part of a strong focus on the stimulation of 'creative people', the White Paper draws on the notion of 'employee-driven innovation', emphasising the competitive advantages of non-hierarchical organisation of work, and close collaboration between employees and employers, as found in the 'Nordic model'. Government will specifically focus how 'employee-driven innovation' may be stimulated and more effectively exploited in the construction sector. Support of creative industries and competitiveness policies are increasingly being interlinked.

Fifth, innovation in the public sector is a new, high priority area of Norwegian innovation policy. Demographic changes will in particular put increasing pressure on the production and delivery of public health and care solutions, making change, innovation and efficiency increasingly important within this sector as a means to achieve 'better solutions for patients and more efficient use of resources' (p. 137). The White Paper indicates hence clearly that innovation in public enterprises generally and within the health sector specifically is a central and integral part of innovation policy. Sixth, as a response to the climate challenges and the financial crisis, a policy has been put in place to support renewable energy technologies, especially off-shore wind power and CCS, thus playing on technologies where the Norwegian economic system shows comparative advantages.

Finally, the White Paper strongly emphasises the key role in innovation for the social dimension, on the importance of social capital, trust and security. It frames an innovation policy, which commits very strongly to the 'Nordic model', and sees that model's commitment to welfare, equality and “flexicurity” as its comparative strengths both in terms of social cohesion and innovative performance.

Within this general framework of STI policy orientation, the internationalisation of Norwegian research has been a top priority in national research policy for a long time (but less so in the national innovation policy). This is manifested in official documents that outline public research policy such as the White Paper on research policy presented to the Norwegian parliament in 2005 where it is stated that: “Internationalisation of research must be a fundamental perspective in research policy with implications for specific priorities”. This emphasis was reiterated in the next White Paper of 2009 on research policy, which expands on this theme:

“Internationalisation of research is important in order to increase quality and strengthen relevance of Norwegian research and in order to provide us with access to research done outside of Norway”. Similar reasons are given in other, and earlier, official documents on Norway’s research policy. In these, Norway’s participation in EU FPs are described and characterized, such as: “EU research and EU Framework Programmes is the largest formalized arena for collaboration between Norwegian and foreign researchers.” In the same White Paper, the following policy goal is given: “Norwegian research policy must contribute to a high degree of internationalisation of research”. Further on in the same 2009 White Paper, the priorities made in the preceding 2005 White Paper were reconfirmed, i.e. that research policy in terms of internationalisation aims at giving priority to four areas: 1) Active participation in the European Research Area; 2) Strengthening of bilateral research cooperation, 3) Norway as an attractive host nation for research; and 4) Norway as a global partner in research.

The latest (2009) White Paper on research policy states elaborates on these goals to strengthen internationalisation of Norwegian research, the following general measures should be taken:

1. Strengthening the national research capability is a prerequisite for coping with global challenges and the international competition for resources for research.
2. National priorities in research policy must be amplified by international research collaboration, and for this reason, more clear priorities for the total international collaboration must be made.
3. The rapid developments in the European Research Area and in EU’s Framework Programmes require clear priorities and goal-oriented measures in order to increase Norway’s benefit from its contribution.
4. Research institutions and firms must become capable of participation in international research collaboration, and they must take responsibility for developing this type of cooperation.

The main strategy for achieving these goals is to strengthen Norway’s participation in EU FP7 and to develop an active policy for participation in the European Research Area (ERA). The sheer volume of research in the Framework programmes is expected to become so large that, due to limited resources, Norway, as a small country, cannot participate in all the policy initiatives launched by the EC, and must therefore prioritize its participation. In parallel with the national participation in the Framework Programmes and the ERA, the attention of the research policy makers is gradually turned to the CIBS countries, but this is also the case with the research policy thinking in EC. Norwegian participation in the future Framework programmes is expected to shape not only R&D networks within the EU but also global R&D networks involving researchers from US, Japan and the CIBS countries.

6.4 The main actors in the Norwegian Innovation System

R&D expenditures in Norway amounted to 37.4 billion NOK, or 1.64 percent of GDP in 2007. It represented a real increase of more than 17 percent over 2005, or 8.2 percent per annum. Table 6.1 breaks down R&D spending by performing sector and funding source. It shows that 53 percent of total R&D activity carried out in Norway was performed by business enterprises; a little more than 15 percent was performed by the government sector; and a little more than 31 percent performed by the higher education sector. About 13 percent of the enterprise sector includes research institutes serving enterprises. Growth of R&D activity in the business enterprises accounted for the largest increase in R&D expenditure. This was mainly driven by rapid growth in R&D activity in the knowledge intensive service industry (NIFU STEP, 2009).

Table 6.1: *GERD by sector of performance and source of funds, millions NOK, 2007*

Sector of performance / ***Source of Funds***	Total intramural	Business enterprise	Government	Higher education
Total intramural	37,396.5	19,945.7	5,727.9	11,722.9
Business enterprise	16,923.7	15,871.3	580.2	472.2
Government	16,780.8	1,728.1	4,631.5	10,421.2
Higher education	229.1	…	...	229.1
Private non-profit	354.4	5.0	34.0	315.4
Funds from abroad (of which)	3,108.5	2,341.3	482.2	285.0
Foreign Business Enterprises	2,234.7	2,107.9	119.3	7.5
-Enterprises in same group	...	1,628.9	...	...
-Other Enterprises	...	479.0	...	...
Other National Governments	145.6	9.8	132.3	3.5
Higher Education	15.0	1.7	8.0	5.3
Private non-profit	39.6	0.3	17.7	21.6
European Commission	481.5	175.2	134.6	171.7
International Organizations	89.9	14.0	70.3	5.6
Not elsewhere classified	102.2	32.4	...	69.8

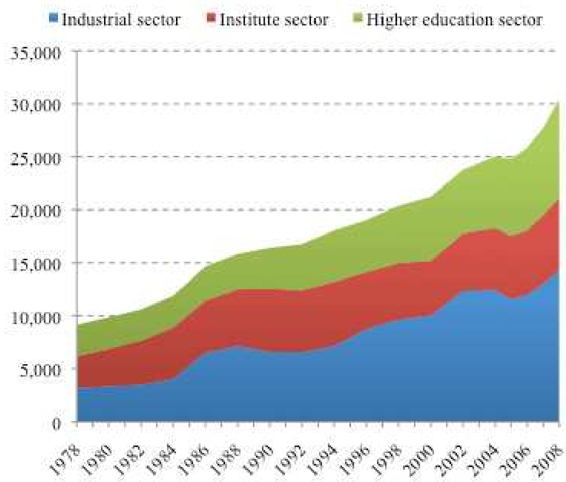
Source: OECD, Research and Development Statistics, 2010.

The relative distribution between the three sectors changed very little during the 2000s. From a longer-term perspective, the three performing sectors follow different development paths. Figure 6.2 illustrates the evolution of gross expenditures in R&D (GERD) activities broken down into the three sectors. In 1978 there were only small differences between the sectors measured in R&D expenditures. Thirty years later R&D in the business sector was twice as high as the institute sector, and the higher education sector had a considerably higher level of R&D expenditure than the Institute sector.

R&D expenditures cover three activities, with differing novelty and risk. In 2007, 18 percent of GERD was spent on basic research; another 37 percent on applied research, and the remaining amount on experimental development. Generally, universities and colleges R&D activity is predominantly basic research, whereas about 80 percent of all experimental development was carried out by business enterprises. The universities and colleges mainly specialize in the medical sciences, while research institutes (increasingly) specialize in natural sciences and engineering. From the point of view of government budget appropriations or outlays of R&D (GBOARD), Norway has a strong specialisation in social science research (probably as a result of knowledge based welfare state policy orientation) and agriculture (especially marine research), as well as in exploitation of earth and land use (as a result of a heavy specialisation in extraction of petroleum and gas), and health care.

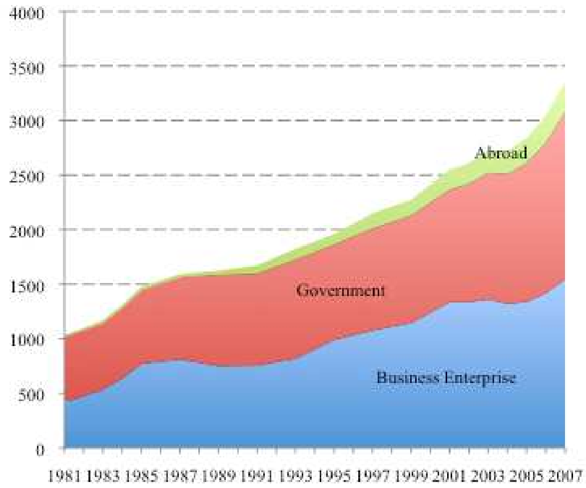
A little more than 45 percent of the R&D activity was financed by the business enterprises and a little less than this percentage by the government, leaving 8.3 percent funded by various foreign sources, plus a residual that includes other national sources including higher education and other non-profit organizations. More than 13 percent of the business enterprise finance comes from the oil companies, and slightly more than 25 percent of the government finance comes from the Research Council of Norway (RCN), which plays an important role in funding all three performing sectors. Of the intramural R&D expenditures financed abroad, which covers contributions made by foreign enterprises, institutions and foreign trusts as well as those from other intergovernmental organizations, almost three-quarters came from the business enterprise sector and over 15 percent from the European Commission. Other actors played a relatively minor role. International finance of R&D activity has increased over the past 25 years. Figure 6.3 illustrates the increasing role that foreign sources of finance have played in Norway since 1981. This figure also shows that there has been a levelling off of the R&D activity financed by business sector in recent years, compared with the other two sectors.

Figure 6.2. *Total R&D expenditure (GERD) in Norway by performing sector, 1978-2008.*



Note: Constant 2000 prices. Million NOK
Source: National Statistics, NIFU STEP

Figure 6.3: *Source of R&D funding in Norway, 1981 to 2007.*



Source: OECD MSTI database, 2009:2.

6.5 International orientation of the Norwegian innovation system

This section describes the scale and scope of the global knowledge networks where Norwegian companies and R&D organisations are involved. In general, the Norwegian business system favours national and international collaboration of many different types. As mentioned, the Norwegian economy is small and heavily relying on export and imports of goods and services. These trade patterns also entail knowledge (technology and know-how) flows facilitated by international networks of customers and suppliers, including suppliers of R&D and other types of knowledge services.

Table 6.2 shows the Intramural R&D financed abroad by the size of the employment of individual enterprises, both by percentage share and percentage of total intramural R&D. While there is considerable variation across time, at least one-third of the enterprises financing their intramural activity abroad have more than 100 employees. These firms are probably foreign multinationals, but there is no data in the OECD globalization database to confirm this. Somewhere between 6 percent and just over 11 percent of total intramural is financed abroad, with medium sized firms having a higher than average percentage.

The economic activity of multinational enterprises in Norway provides an indication of the extent of globalized networks that are centred abroad. Table 6.3 shows this activity in the Norwegian manufacturing sector by investment country and by six different economic indicators. In 2006, at least640 enterprises, or 3.3 percent of the Norwegian economy were foreign owned enterprises, which made up almost 24 percent of the total employment in manufacturing, over 31 percent of production output, and over 27 percent of value added. Over 29 percent of investment in fixed capital came from foreign enterprises and about a third of R&D activity was performed by foreign enterprises. As one might expect, Denmark and Sweden were major players in Norway in terms of the number of enterprises or networks, but the United States was the major player in terms of R&D performed in Norway. Usually, R&D that is performed abroad by an enterprise on the technology frontier is seeking to develop or acquire certain knowledge-based assets. This motivation may also have been true for many of the foreign affiliates from Sweden and the United Kingdom. The only investment in Norway from the CIBS countries appears to come from Brazil, who has been making considerable investments in the energy extraction industries.

Using information from the Norwegian R&D survey, Herstad, Kaloudis, and Sandven (2006) made four findings that help explain Table 6.3: (1) Most foreign-controlled in-house R&D is not motivated by the Norwegian innovation system or public incentives, but by their in-house competences; (2) Norwegian characteristics often generate R&D activity in foreign-controlled firms, especially in the petroleum industry, in an effort to develop their absorptive capacity and adapt their products to the local market; (3) Own revenues are overwhelmingly the most important source of

Table 6.2. *Intramural R&D financed abroad by size of enterprise, 1999 to 2007.*

	1999	*2001*	*2002*	*2003*	*2005*	*2006*	*2007*
Total in million NOK	633	968	738	1,089	1,331	1,264	1,976
Percentage share of intramural R&D financed abroad							
Total	100	100	100	100	100	100	100
10 to 19	7.0	8.7	3.6	3.5	1.6	2.3	11.0
20 to 49	12.5	9.7	29.2	18.9	8.3	8.1	5.5
50 to 99	12.2	16.5	30.1	13.2	14.8	10.4	9.4
100 to 199	25.7	15.5	21.7	14.0	23.2	27.3	26.8
200 to 499	21.4	11.5	6.1	22.0	21.7	25.7	17.5
500 and more	21.1	38.2	9.1	28.4	30.3	26.3	29.9
Percentage of total intramural R&D expenditure financed abroad							
All (10 and more)	6.6	7.7	6.0	8.1	9.8	8.3	11.4
10 to 19	7.0	7.9	2.0	2.5	1.5	2.0	13.2
20 to 49	11.2	4.8	12.9	10.0	5.8	5.2	5.4
50 to 99	5.6	15.6	16.7	8.3	12.9	7.7	8.4
100 to 199	14.9	8.5	8.2	9.5	19.5	18.7	26.1
200 to 499	15.8	7.3	3.8	12.9	15.6	18.6	15.4
500 and more	2.8	7.0	1.4	6.5	7.6	5.1	8.1

Source: Statistics Norway

finance for intramural R&D activities, accounting for 75 percent and 70 percent of R&D budgets for Norwegian and foreign-owned firms respectively; and (4) R&D in foreign-controlled subsidiaries is less dependent on public financing than R&D in Norwegian-owned firms. Lower dependence on own revenues and public financing is related to a higher dependence on the headquarters as source of finance. The study is based on the enterprise-level data collected through the Norwegian R&D survey.

Extramural R&D expenditures provide a good estimate of amount of R&D performed abroad but financed by domestic institutions. These include all R&D expenditures contracted to other enterprises and organizations, which may include other enterprises and organizations within the country. Table 6.4 shows that the large and medium sized firms with 100 or more employees explain around one-third of the extramural R&D performed abroad. These are mainly multinationals headquartered in Norway. The percentage of total extramural R&D performed abroad varies both across time and across size class, which indicates no clear pattern. More than one-half of the extramural R&D activity is done in the energy extraction industries (mainly petroleum and gas), but the percentage of extramural R&D performed abroad does not vary to any great degree from the national average. Chemicals, which includes pharmaceuticals in this table, makes up almost 10 percent of the extramural R&D activity and the percentage of this activity performed abroad is double the national average.

Table 6.3. *Inward activity of multinationals in manufacturing by investing country, 2006, millions of NOK and percentage share.*

	Number of enterprises	Number of employees	Production	Value added	GFCF	R&D expenditures
World	640	60,944	192,314	53,823	6,306	1,692
Percentage share of total Norwegian economy	3.3	23.9	31.2	27.4	29.4	33.3
Percentage share of total activity of multinationals:						
EU-25 *Of which:*	68.8	65.9	...	...	...	50.6
Denmark	11.4	12.8	12.6	7.9	9.0	3.1
Germany	6.4	5.8	4.1	5.3	45.1	3.9
Italy	0.5	0.4	0.4	0.3	0.4	...
Sweden	24.7	19.1	10.8	11.4	10.4	15.4
United Kingdom	11.4	11.4	8.2	8.3	70.8	11.7
United States	11.1	24.4	23.2	27.7	23.6	36.1
China	0.0	0.0	0.0	0.0	0.0	0.0
India	0.0	0.0	0.0	0.0	0.0	0.0
Brazil	0.2	0.1	...	...	...	...
South Africa	0.2	0.1	...	...	...	...

Source: OECD Globalization database, 2010.

Several studies that focus different aspects of outward R&D in Norway. In a study of 35 of the largest multinational enterprises, Narula (2002) found that large Norwegian multinational firms tend to concentrate R&D at home because they are embedded in the national innovation system and they ‘fit’ well in the industrial structure of Norway. Only 5 percent of corporate R&D staff is in this group located abroad. Herstad and Jonsdottir (2006) analyzed the relationship between different Innovation systems and domestic multinational enterprises. Market access was found to be the main driver of corporate internationalization, but found that the decision to invest in R&D activity abroad was much more complex than what traditional theory suggests. It also finds that domestic multinational enterprises are key actors in the Norwegian innovation system, and that they serve as a knowledge pipeline to the global economy.

Drawing on information from 218 *domestic* multinationals, Gulbrandsen (2008) found that the main reason for international extramural R&D activity was more competence-oriented rather than capacity and accessibility-oriented. The survey indicates that Norwegian domestic multinationals are generally satisfied with the national R&D infrastructure, and are reluctant to invest in extramural R&D abroad because of the fear of losing their property rights and other proprietary knowledge, but they also found it necessary to invest abroad to gain certain competences that were not available in Norway. Gulbrandsen and Godoe (2008) confirm these findings through case studies of the strategic behaviour of eight enterprises.

Table 6.4. *Extramural R&D performed abroad by number of persons engaged, 1999-2007*

	1999	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
Total NOK mil.	1,365	1,381	1,005	908	1,274	1,105	1,169	1,666
Percentage share of extramural R&D performed abroad								
Total percentage	100	100	100	100	100	100	100	100
10 to 19	1.9	2.8	13.9	6.4	7.4	6.4	7.4	7.2
20 to 49	1.9	18.1	8.0	8.7	16.1	9.0	3.9	9.4
50 to 99	6.5	3.4	5.2	10.1	8.6	4.8	7.4	4.0
100 to 199	7.7	9.1	7.8	13.5	12.8	16.8	17.1	7.4
200 to 499	19.4	25.9	8.8	10.6	7.0	17.0	17.5	13.8
500 and more	62.6	40.7	56.3	50.7	48.1	46.0	46.6	58.1
Percentage of total extramural R&D performed abroad								
All (10 +)	36.2	33.0	28.9	25.5	32.3	27.3	30.9	34.6
10 to 19	79.9	19.0	26.9	28.8	35.2	29.5	51.3	31.2
20 to 49	13.4	44.3	19.4	22.1	37.9	30.5	20.3	40.6
50 to 99	23.4	15.4	24.2	29.1	32.1	18.8	25.4	18.3
100 to 199	21.2	31.6	22.0	27.1	34.4	34.7	35.4	24.5
200 to 499	40.1	34.9	23.9	17.7	16.5	27.1	40.2	34.1
500 and more	42.4	33.4	35.4	27.3	34.4	25.7	27.6	38.8

Source: Statistics Norway

6.6 Knowledge flows and global networks in the Norwegian innovation system

Business enterprise technological collaboration is an important feature of the Norwegian innovation system. Table 6.5 provides an overview of the collaboration patterns of innovative Norwegian enterprises. Firstly, they tend to seek collaboration with many other types of knowledge providers and they do that in greater extent than innovative enterprises from other countries. Secondly, it is evident that the main collaboration interactions are taking place within the value chains, that is, with technology suppliers and with clients or customers. Collaboration with R&D organisations occurs also occasionally but it is not as broad and intense as collaboration within the value chains. Obviously, the more international the value chains of the Norwegian companies are the more likely it is that they collaborate with suppliers and customers abroad. Table 6.5 and 6.6 shows that national collaboration networks still dominate, but EU and USA are areas with which Norwegian enterprises have a significant number of innovation oriented collaboration links.

Research collaboration is mainly located in universities and research institutes, but occasionally also in business enterprises. In 2008, more than half of all Norwegian papers in international scientific journals were co-authored by researchers outside Norway. Table 6.7 shows the extent of this collaboration based on journal publications over two three-year periods, 1997 to 1999 and 2007 and 2009. The total number of research collaborations increased by almost 250 percent over the past decade, indicating that research-based international networking is increasing rapidly and has become more complex. The table also shows that more than half of all collaborative activity is done with other researchers in the United States, United Kingdom, Germany, Sweden, and Denmark. When adjusted for the size of the population, it becomes clearer that Norway is part of a large and extensive research network within the Scandinavian countries and that socioeconomic and cultural ties influence the development of these networks.

The extent of co-patenting also indicates that Norway is part of a large global research network with Scandinavia as a gravitational focus point. Table 6.8 describes the evolution of international patent applications made by Norwegians with foreign inventors filed under the Patent co-operation Treaty (PCT). It shows that the share of patents with foreign co-inventors is rather stable over time, but it also indicates that the percentage of patents with co-inventors is twice the average percentage observed in the European Union. The table also confirms that the United States, United Kingdom, Germany, Sweden, and Denmark are the most important countries in Norway's innovation network.

Table 6.5. *Percentage of enterprises with innovation activities in Norway, 2004 and 2006.*

Enterprises with innovation activities	2004	2006
All types of cooperation	33.2	29.6
Of which:		
National	30.9	23.0
within other Europe	19.3	11.8
within United States and other countries	9.7	8.0
Other enterprises within your enterprise group	14.0	7.3
Competitors or other enterprises of the same sector	11.9	6.5
Clients or customers	22.3	15.6
Suppliers of equipment, materials, components or software	23.1	17.5
Universities or other higher education institutions	14.8	10.8
Government or public research institutes	16.3	9.9
Consultants, commercial labs, or private R&D institutes	20.3	15.1

Source: Eurostat Community Innovation Survey 2004 and 2006.

Table 6.6. *Percentage of innovative enterprises by collaboration type and geographical type, 2001*

	National	EU and EFTA	Eastern Europe	USA	Japan	Other
Any type of innovation cooperation	33.4	15.3	1.1	5.7	1.5	3.2
Cooperation within enterprise group	10.1	7.5	0.2	2.6	0.3	1.0
Cooperation with equipment suppliers	16.3	7.4	0.2	2.1	0.6	1.5
Cooperation with clients or customers	16.4	5.0	0.5	2.5	0.6	0.9
Cooperation with competitors	4.8	1.6	0.1	0.5	0.1	0.3
Cooperation with consultants	11.8	1.7	0.1	0.6	0.0	0.2
Cooperation with Commercial labs	5.8	1.9	0.0	0.5	0.0	0.2
Cooperation with Universities	9.5	1.8	0.1	1.0	0.1	0.3
Cooperation with Government or research institutes	10.9	1.4	0.1	0.4	0.0	0.2

Source: Eurostat Community Innovation Survey 2001.

Table 6.7. *Research collaboration with Norwegians based on journal publications, 1997-1999 and 2007-2009.*

2007-09	Records	Percentage	1997-99	Records	Percentage
Norway	27,364	100	Norway	11,879	100
United States	4,362	15.9	United States	1,416	11.9
Sweden	2,875	10.5	Sweden	1,220	10.3
England	2,615	9.6	England	791	6.7
Germany	2,464	9.0	Germany	773	6.5
Denmark	1,842	6.7	Denmark	698	5.9
China	505	1.8	Brazil	113	0.9
South Africa	262	1.0	China	72	0.6
Brazil	200	0.7	India	32	0.3
India	137	0.5	South Africa	22	0.2

Source: ISI Web of Knowledge, 2010

Table 6.8. *International cooperation in patents with Norway, Patent office & Triadic Patent Families, 2000-2007*

	2000	2001	2002	2003	2004	2005	2006	2007
Total Patents with cooperation abroad	666	621	657	546	657	716	741	706
Percentage with foreign co-inventor(s)	18.9	17.7	22.7	15.0	17.0	18.6	21.6	22.5
EU27	13.8	14.2	15.5	10.6	12.0	14.8	15.1	16.9
Denmark	1.3	0.3	1.8	0.5	0.6	0.1	0.4	1.1
Estonia	...	...	...	...	...	...	...	...
Germany	3.6	3.7	4.1	1.6	2.6	2.6	3.0	1.7
Italy	...	0.5	...	...	0.3	0.3	0.4	0.4
Sweden	4.0	3.9	2.6	3.7	3.8	6.6	4.6	4.5
UK	2.8	3.1	4.0	2.4	2.7	2.6	3.6	5.5
USA	3.7	3.5	5.6	4.6	3.8	2.5	5.1	5.2
China	...	...	...	...	...	0.8	0.3	0.4
India	...	...	...	0.2	...	0.1	...	...
Brazil	...	...	...	...	...	0.1	...	...
South Africa	...	0.2	0.1	...	0.1	0.1	...	0.1

Note: Reference date. Patent applications filed under the Patent Cooperation Treaty
Source: OECD patent database

6.7 Concluding remarks on Norwegian networks of innovators

The Norwegian innovation system relies heavily on knowledge intensive production processes within the energy extraction, metals and maritime related industries, yet it contains considerable diversity. Norway is becoming an increasingly important player in knowledge intensive business services (mainly software and telecommunications) and renewable energy resources. Most firms in the petroleum and natural gas sector are fairly large, whereas they are fairly small in the renewable energy sector and in the business services. The non-renewable energy sector and related industries fits well into the layer that Wicken (2008) describes as large-scale knowledge intensive enterprises that rely on collaborative learning, while the renewable energy sector relies on collaborative learning with other enterprises and research organizations that operate within global innovation networks. Many large multinationals enterprises, including Halliburton, ExxonMobil, ConocoPhillips and Dutch Shell Technology, have set up R&D facilities in Norway, mainly to become part of the global knowledge network in the energy extraction industries. Enterprises in the Norwegian petroleum sector are specialists in deep-water conditions and horizontal drilling. Some domestic multinationals, including Statoil, Hydro Aluminium, Aker Group, and Norske Skog, have set up R&D facilities abroad (Shapira, 2009).

Only a few large firms dominate total intramural R&D spending in Norway, but many of the smaller enterprises purchase R&D from both domestic and global enterprises rather than doing it themselves. Unlike the large enterprises, which coordinate production, marketing, and R&D activity from a central location, a majority of the small Norwegian enterprises become involved in self-organized networks of innovators that facilitate collaborative learning with other enterprises and research organizations. Relatively small enterprises in the solar panel industry have located R&D facilities in Germany and the United States to access the global innovation network.

Cooperative relationships within the innovation network can take on different forms, and the scale and scope of Norwegian participation is quite extensive. They are most extensive within the Nordic region, and especially Denmark and Sweden. Despite having very different economic structures, the Scandinavian countries are the most important nodes in the Norwegian innovation network, mainly because of social, cultural and various linkages in their institutional frameworks. Germany, the United Kingdom, the rest of EU27 and USA also represent important nodes in the innovation network. Norway's network of innovators also extends to the CIBS countries, where China and India are becoming increasingly more important, mainly due to increased trade activities, larger and broader policy platforms for research, innovation collaboration, and the recent EU policy agenda. Norwegian R&D and innovation policies are also moving towards this direction, strengthening both the Nordic innovation networks, but also those further afar.

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