1. Knowledge transfer and technology diffusion: an introduction

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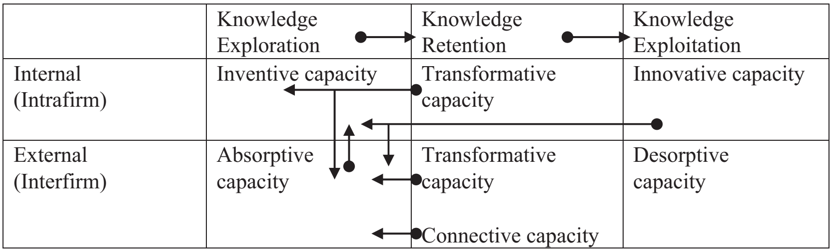
1. DIFFUSION AND DEVELOPMENT

For present purposes, diffusion can be defined as the spread of knowledge from an original source or sources to one or more recipients. From an economic standpoint, the efficient diffusion of knowledge on new technologies is an essential characteristic of growth and development. In itself, new knowledge has no economic value until it has been used productively – the more widely a particular bit of knowledge can be used, the greater its value becomes (Robertson and Patel, 2007). This is, of course, hardly a secret. Diffusion, along with innovation and implementation, is one of the three building blocks of the influential Linear Model of Innovation (Godin, 2006), but it remains a nebulous field in many respects despite a vast literature on various aspects. The problem is not conceptual so much as practical because, while diffusion is easy to define, it is often difficult to accomplish. As a result, knowledge that might be broadly useful tends to be restricted to narrow areas for unnecessarily long periods of time, retarding economic performance.[1]

Although the Linear Model of Innovation has been discredited in many respects (Kline and Rosenberg, 1986), its basic building blocks of innovation, diffusion and production or implementation remain central to technology studies. Nevertheless, much as was true in the early post-World War II period when the model was originally developed (Godin, 2006), the general thrust of conceptualization and empirical research remains heavily focused on the innovation stage, without much attention given to feedback or other complications. The Linear Model has also been the framework for the New Growth Theory models that have been popular for the past two decades (for example, Romer, 1986, 1990, 1994). The popularity of the Linear Model is easy to explain. In it, the activities surrounding innovation are the triggers for the entire sequence: if innovation is not undertaken wisely, the whole subsequent series of events will be impaired. In addition, innovation has long been characterized as a



Source: Adapted from Lichtenthaler and Lichtenthaler (2009), Figure 1, p. 1318.

Figure 1.1 Knowledge capacities

rational process that, at least up to a point, can be managed. Innovation is therefore regarded as a good target for government policy because, if the Linear Model is accepted, then a smoothly functioning innovation system is assumed to activate a chain of events including diffusion and the ultimate deployment of the new knowledge that has been generated by expenditures on research in pure science and industrial R&D.

The diffusion and use of new knowledge, on the other hand, cannot be schematicized as easily because they are grassroots activities, undertaken in diverse environments in order to meet particular needs which may seem trivial to outsiders but can affect the viability of individual organizations and entire industries. Thus they are messy and irregular processes that are hard to summarize in a few precepts that policy makers can use as levers for change. Furthermore, for analysts of a neo-classical bent, there can be no serious problems surrounding diffusion and implementation because they are assumed to occur automatically in a world of rational and perfectly informed actors.

As Lissoni and Metcalfe (1994) have argued, however, there are several distinct approaches to diffusion. In recent years, these have come together and, '[a] much richer pattern is emerging which distinguishes technology in terms of knowledge and skills as well as discrete artefacts' (p. 106). Newer trends in research are more complex and nuanced, and more attuned to the real world (Tunzelmann, 2002), in which diffusion and implementation are not frictionless, costless or instantaneous. In a recent article, for example, Lichtenthaler and Lichtenthaler (2009) outline a series of 'knowledge capacities' that firms need in order to move through the entire innovation process from planning to implementation (Figure 1.1).[2] These reflect the diverse and non-linear nature of the problems faced over the course of the process.

The categories of knowledge exploration, retention and exploitation do not correspond directly to the Linear Model. In order to engage successfully in receiving knowledge diffused from outside, organizations cannot rely on absorptive capacity alone (Cohen and Levinthal, 1989, 1990). As well as possessing an understanding of externally generated knowledge, it is valuable to establish and maintain external relationships that simplify the search for useful new knowledge (connective capacity) and to be able to put knowledge in a form that meets an organization's particular requirements (innovative capacity). Individually and collectively, these capacities call upon significant management activity to build, coordinate and mobilize the skills that form their foundations. Moreover, different societies – and firms with varying organizational cultures within a single society – are likely to have strengths in different combinations of knowledge capacities. A large part of the managerial mission, therefore, is to identify and develop those capacities that are weak and to ensure that their organizations have the requisite dynamic capabilities (Helfat *et al*., 2007; Teece, 2009) to create and deploy the full range of knowledge capacities when and where they are needed.

Taken together, these activities encompass a degree of diversity that policy makers and scholars may find daunting. How can they design instruments to encourage diffusion when the mechanisms are so varied and may even be contradictory across different cases? And yet it is clear that diffusion is an essential driver of any system for generating and using technological knowledge. As we argue in Section 2 of this chapter, most organizations in any economy are not at the high technology end of the spectrum, no matter how this is defined. Because these low and medium technology (LMT) organizations account for well over 90 per cent of output and employment in even the most advanced economies, any productivity improvements that they make can, in aggregate, greatly affect overall levels of economic performance and welfare. Equally significant are the very substantial markets that LMT organizations offer for many high-tech products, generating the profits needed to cover past research costs and to encourage future investment in R&D (Robertson *et al*., 2003). Widespread diffusion of knowledge in LMT sectors is therefore a central cause as well as a result of research leading to high-tech breakthroughs.

In this book, we address several (but by no means all) of the questions associated with diffusion of new knowledge to and within LMT industries, especially by small and medium size firms. Our objective is to expose some of the mechanisms that these firms use in gaining access to new knowledge developed externally and then transforming it for their own purposes. The next two sections briefly outline the importance of new technology to LMT organizations and the role of knowledge in the diffusion process.

These are followed by discussions of innovation in industrial districts (IDs) and of LMT sectors in developing economies. In the final section, we offer suggestions for further research on diffusion.

2. TECHNOLOGICAL INNOVATION IN LOW AND MEDIUM TECHNOLOGY SECTORS

All of the contributions in this book concentrate on technology diffusion in low and medium technology manufacturing sectors. Technology levels are measured by the OECD (Hatzichronoglou, 1997) based on the share of firm revenue that is reinvested in research and development. In high-tech industries, the share is greater than 5 per cent; in medium-high-tech industries, between 3 and 5 per cent; in medium-low-tech industries, between 1 and 3 per cent; and in low-tech industries, less than 1 per cent (Smith, 2005). The assumption is that investment in R&D is directly correlated with the degree of innovation in an industry and with its rate of growth. As innovation and growth are posited to be good for the economy and for society, high technology industries have been granted preferential treatment by governments while the roles of other sectors have been dismissed as being relatively unimportant for welfare (Hirsch-Kreinsen *et al.*, 2006; Robertson *et al.*, 2009).

LMT industries are defined as those that are not high-tech, that is as sectors that devote less than 5 per cent of their revenue to R&D. They include not only most manufacturing production, but almost all branches of the service, agricultural and mining sectors.[3] LMT industries in general are 'mature' in the sense that they are well advanced along their life cycles. Their outputs are usually well-established in the minds of their customers and their rates of growth are no longer high,[4] especially by the standards of high-tech industries. Levels of both product and process innovation tend to be low by conventional measures (Heidenreich, 2009) and, when innovation does occur, it is incremental rather than radical. Taken as a whole, however, LMT sectors are far from technologically stagnant and their role in economic dynamics is very large.

The extent of the attention accorded to high-tech industries and the relative neglect of LMT industries derive from several misunderstandings or logical distortions. Firstly, in an empirical sense, the importance of high-tech sectors to the economy is generally overemphasized. Even in very large economies such as those of the USA, the EU and Japan, high-tech industries rarely account for as much as 10 per cent of manufacturing activity, and their share in services, agriculture and other sectors is substantially lower. Thus only about 1 to 2 per cent of economic output can be attributed to high-tech industries even in advanced economies (Robertson and Patel, 2007). As LMT sectors comprise such overwhelming shares not only of output, but of employment and investment, it is clearly vital to ensure that they perform well. For example, as Sandven *et al*. (2005) have shown, the combined contribution of medium-low and low-tech sectors to growth in OECD member countries in the last two decades of the twentieth century (34.8 per cent) was greater than that of high-tech sectors (32.7 per cent). Furthermore, LMT industries are notable contributors to the well-being of high-tech sectors because they are often their major customers. In the absence of sales to LMT firms, the return on investment in R&D by high-tech firms would be considerably reduced, leading to reductions in R&D expenditures and growth (Robertson and Patel, 2007). Finally, innovations originating in LMT industries are substantial contributors to improved productivity in high-tech sectors, as well as the other way around (Hauknes and Knell, 2009).

These facts point to a major shortcoming in the implicit theorizing favoured by analysts and policy makers who advocate special support for high-tech sectors and effectively disregard the performance of the rest of the economy. Modern market economies do not grow linearly on a sector-by-sector basis, nor is growth simply the result of increased inputs such as larger investments in R&D. Instead, economies operate on the principle of a 'circular flow' (Schumpeter, 1934) in which organizations are both consumers and producers that convert inputs (produced by themselves or bought in the market) into outputs that are then sold to others. Although some developing nations may have 'dual economies' in which modern and traditional sectors are only loosely linked (Robertson *et al*., 2003), in developed countries the viability of any sector depends ultimately on effective demand, that is on the willingness and ability of consumers to pay for its outputs. Even when external demand from other countries, which may be substantial in some cases, is considered, the point remains that the functioning of a sector is in general heavily dependent on the performance of the economy, broadly or narrowly defined, in which it is embedded. This, in turn, depends on the overall level of efficiency within the economy and not just on the efficiency of any sector regarded in isolation. Improved productivity must be widespread – rather than restricted to a few, generally small, high-tech fields – in order to avoid the creation of bottlenecks that will eventually retard the economy as a whole. The implications of this for most high-tech sectors in advanced economies are even stronger, because the major consumers of their products are, ultimately, in LMT sectors. In short, while high-tech industries are indeed vital to a well functioning economy, their value derives in large part from their interactions with the much larger LMT sectors. Therefore, any set of policies that allegedly favours high-tech over LMT sectors is seriously deficient because a wide range of sectors with varying characteristics must interact efficiently for an entire economy to perform well.

It is also necessary to choose the proper time horizon when formulating policy. Economic sectors expand and contract as technology and other conditions change. To take an obvious example, steam power generation and the production of steam engines have been replaced by electricity and equipment for generating electrical power. Furthermore, it is clear that the growth of most industries slows as markets become saturated, and also that this maturity is often accompanied by a reduction in the rate of innovation (Utterback, 1994). It is rare, however, for new industries of economic significance to replace older ones quickly since high rates of growth are applied to low initial bases. In the meanwhile, older industries continue to be substantial employers and producers of goods that markets demand, even as they reach maturity and their growth levels off. More importantly, some large industries are unlikely to ever be eliminated because they provide products for which there are no satisfactory substitutes. Motor vehicles may have replaced trains for many uses over the course of a century, but the food industry remains at the centre of human life as it has been for thousands of years. The evolution of food processing illustrates our point that technological change in mature LMT industries is a crucial source of economic welfare. Because of the sector's heavy weighting, even modest improvements in productivity can be major contributors to overall economic performance. Thus even as the economy goes through periods of Schumpeterian transformation, in which the main drivers of economic change move from sector to sector, a process which Schumpeter (1939) himself measured in terms of cycles of approximately half a century, it is necessary to keep the core of existing economic activity as healthy as possible by encouraging innovation in the short and medium terms wherever it will yield a positive return.

3. KNOWLEDGE AND DIFFUSION IN LMT SECTORS

Because of their low levels of investment in formal R&D, LMT organizations have always engaged in 'open innovation' (Chesbrough, 2003) – in buying many of their new technologies or otherwise acquiring them from external sources instead of developing them internally. This can raise important issues in product development because a great deal of effort may be needed to successfully blend new and old knowledge, acquired from both internal and external sources (Morone and Taylor, 2010; Oerlemans *et al.*, 2000). For example, as Thierry Rayna and Ludmila Striukova show in Chapter 8 in this volume, the development of the modern electric guitar involved a great deal of experimentation over decades in order to determine which aspects of traditional guitar design and manufacturing were appropriate for the new instruments.

However, in part because of the tendency of low-tech firms in particular to operate in relatively highly saturated markets in which price competition is important, they have tended to emphasize process innovation[5] and to rely heavily on embodied technology as innovations are acquired through the purchase of equipment that includes developments that often originated in other parts of the economy (Pavitt, 1984). But it is naive to believe that innovations can usually be acquired on a 'plug and play' or 'turnkey' basis in which they are useable without any further inputs such as tacit knowledge. In mature industries with well developed asset bases, this is especially unlikely because new equipment frequently needs to be fitted into a larger production process dominated by existing equipment. To ensure compatibility across the entire asset base, adjustments must be made to the new purchases, to the remaining existing assets, or to both. Important modifications in organizational routines (Nelson and Winter, 1982) may also be needed. All of these changes are likely to be organizationally specific because of subtle or large differences in equipment and routines among organizations. As a result, managers may need to develop local solutions even when the problems they face are very general. Of the knowledge capacities referred to in Figure 1.1, this requires at least a combination of absorptive and transformative capacities.

Practices used to promote high-tech innovations in high-tech environments may not be appropriate for LMT organizations (Liagouras, 2010). Tödling *et al.* (2009) suggest that while extensive internal R&D is needed in the introduction of advanced innovations, less internal R&D (largely to maintain absorptive capacity (Cohen and Levinthal, 1990)) is needed for the introduction of products that are only new to the firm (as is common for LMT organizations) and that this is generally accompanied by external knowledge acquired through cooperation with service firms such as suppliers. Limited internal R&D may be supplied by 'peripheral inside innovators' who 'are not responsible for innovative activity by their job description, but nonetheless [are] interested in and [have] the potential to produce innovative ideas and contribute to the innovation process by suggesting, supporting, or refining innovative concepts' (Neyer *et al.*, 2009, 411).

These peripheral inside innovators can be production engineers or mechanics responsible for making the adjustments needed to validate incremental innovations in existing systems. Even when service firms are called upon, the innovating organizations need to contribute to, and to supervise, the introduction of innovations because they are more aware of aspects of technical and strategic requirements than outsiders can be (Brusoni, 2005).

Nevertheless, the main problem in knowledge use by LMT firms may be to find the knowledge in the first place. Even when valuable knowledge is available, this does not mean that organizations that could benefit from its use (problem holders) know where to find it or that recognized paths for locating knowledge are available. Equally importantly, firms that have valuable knowledge that they would like to commercialize (solution holders) do not always have good ways of making contact with possible customers (Robertson, 1998). In the diverse and segmented situations that prevail in modern economies, possible innovations may emanate from a huge number of sources, and while some locations may seem a priori to be more likely to yield valuable results than others, the most important innovations may, in fact, originate in areas that are not often considered (Granovetter, 1973). This is especially important for small organizations that lack the resources needed to meet extensive search (or, in the case of suppliers, advertising) costs, a category that includes most LMT firms both in advanced economies and especially in developing economies.

If LMT organizations are to maintain, or better yet improve their competitiveness, they need to find ways of coping with the knowledge problems that are at the core of innovation. While in some cases, these smaller firms in mature industries are more sceptical of the benefits of change than high-tech firms, their status as 'later adopters' (Rogers, 2003) is the result of their inability to find and implement knowledge that they need to solve problems. The mechanisms used by LMT firms to overcome the obstacles posed by a lack of knowledge (ignorance) in the face of competitive threats by better informed rivals are the main topic of this volume, and are discussed further in Sections 4 and 5 of this chapter.

Networks, especially industrial districts (IDs) and clusters, are a widespread approach to finding a shortcut to locating important knowledge (Beccatini *et al.*, 2009; Porter, 1998). These arrangements allow firms to economize on search costs by creating 'strong ties' (Granovetter, 1973) among firms that formally and informally trade information relatively freely. In practice, however, reduced search costs for smaller firms are available only for information generated within a district, while superior information from outside must be accessed through larger, or 'leading' firms that function as 'gatekeepers' (see the special 'clusters' issue of *Regional Studies*, 2008). As long as the important information is generated within a particular ID or cluster, this is not a problem, but clusters can be vehicles for stagnation when important innovations are beyond the normal channels cultivated by the gatekeepers (Menzel and Fornahl,

2010) or when the gatekeepers do not share their new knowledge equally among district firms but favour some over others. Membership in multiple networks may reduce this problem to some extent (Robertson and Smith, 2008), but cannot guarantee that sources of innovation are tapped efficiently.

The schema of Lichtenthaler and Lichtenthaler (2009) helps to tie these threads together by acknowledging the relationships between internal and external capabilities for finding and processing knowledge in innovative situations (Figure 1.1). All of the knowledge capacities that they discuss reside within an organization even if some of the knowledge has originated externally. As they demonstrate, if organizations are to innovate successfully – as they must in general do in competitive situations – they cannot expect outsiders to do all of the work for them, even if they pay for the services: organizations need to develop their own knowledge skills in order to make sense of other people's knowledge. Furthermore, this is a dynamic process in that areas of ignorance may not become evident until firms need to cope with newly acquired knowledge.

Thus 'transformative capacity' (Figure 1.1) refers to an organization's ability to retain and recycle knowledge after it has been internalized, to make sure that nothing useful is lost from a growing database of knowledge. This growing fund of knowledge[6] then feeds back into absorptive capacity in order to increase an organization's ability to acquire external knowledge in the future. Organizations use 'connective capacity' to maintain relationships with external knowledge sources and to improve their chances of gaining future access to knowledge held by partners if they need to, perhaps transferring some of their own knowledge to ease the process. This again should strengthen absorptive capacity in the future. Finally, 'innovative capacity' is the ability to use new knowledge to create new solutions, while a firm's 'desorptive capacity' refers to its skill in marketing knowledge that it has generated internally. This may be restricted to new product development, as Lichtenthaler and Lichtenthaler suggest, but it can also extend to process improvements and to making adjustments to improve the assimilation of knowledge and artefacts (embodied technology) brought in from external sources. Taken together, these capacities frame the general guidelines for knowledge acquisition and deployment by LMT organizations while emphasizing that each stage also involves learning in order to make adequate use of knowledge gained in the past.

The following two sections discuss how LMT firms in industrial districts and in developing countries are responding to competitive pressures to modify their current roster of capacities to engage in innovation. As most of the contributions to the volume are case studies, they provide a rudimentary foundation for a set of techniques that LMT firms can use to improve knowledge diffusion and their own innovative capabilities in the future.

4. DIFFUSION IN SPATIAL AGGLOMERATIONS

There is a huge and growing literature on clusters and industrial districts, and on the impact of spatial proximity on the success of these spatial agglomerations.[7] There are two broad types of concentrations of firms, one in which the firms are from a variety of different industries or sectors, and the other in which they are from the same or closely related industries or sectors. The processes leading to the first – different sectors and subsectors of manufacturing and services – are associated with the development of cities. The second, more industrially homogeneous concentrations of firms, are known as industrial agglomerations (Jacobson *et al.*, 2002). In this book, we are concerned mainly with the latter.

As a dynamic process, industrial agglomeration is what happens when firms set up close to other firms to derive certain benefits. Marshall (1920) addressed these benefits as the three advantages of localization. In the context of diffusion, the most important is where people involved in the same industry live and work in close proximity to one another, so that new products, 'and improvements in machinery, in processes and the general organization of the business' become quickly known and copied (Marshall, 1920, iv.x.7). This is what Krugman (1993, 52) refers to as technological spillovers, 'the more or less pure externality that results from knowledge spillovers between firms'.

Marshall's (1920) other two advantages of agglomeration are: the 'growth of subsidiary trades', where both firms in an industry and those producing intermediate products are close to one another; and the development of a local labour market of relevant skills, or labour market pooling. These may also enhance diffusion of innovations; an innovation by a spatially proximate supplier of inputs – especially of such key inputs as machinery – will quickly diffuse to all the local users through face-to-face communication. And new skills will similarly diffuse rapidly among similarly qualified and/or experienced workers living and working in close proximity.[8]

These ideas are in essence about how social aspects of a community impinge on economics. Without prioritizing either social or economic factors, it can be suggested that economic interactions are in some sense embedded in the structures of social relations (Granovetter, 1985). Marshall's ideas suggest, further, that the degree of embeddedness may be related to innovation and the rate of diffusion. We address this issue later in this section.

Marshall's (1920) 'growth of subsidiary trades' is similar to what Porter calls 'related and supporting industries' (Porter, 1998). These are producers of inputs, or providers of services that are used by the industry. They may also include industries that use the same or similar inputs, machinery or skills. Aircraft production and automotive production are, for example, both customer industries of the machine tool industry.

Marshall's ideas have been used extensively to explain 'industrial districts'; indeed he was the first to provide both the conceptual and empirical explanations for IDs. Industrial districts were noticed in the post-World War II period as locations, typically villages, especially in Emilia-Romagna in Italy, where 'a myriad of firms specialized in various stages of the production of a homogeneous product, often using flexible production technology and connected by extensive local inter-firm linkages' (Andreosso and Jacobson, 2005, 192[9]). As small, owner-managed firms, often with other members of the family also working in the firm, their internal communication lines are short. In addition, flexible production requires most people working in the firm to be able to do most of the jobs. Organizationally, this implies an absence of long top-down chains of authority: firms in industrial districts have relatively flat organizational structures. Between firms, while there is competition at some levels, at others the activities of these independent firms are strongly coordinated; they contribute to the production of the same good within the same geographical area (for example, toys in Canneto sull'Oglio in Lombardy). These geographically defined districts are said to form a 'social and economic whole' and were at least in part responsible for the rejuvenation of the dormant economy of the Third Italy (Best, 1990, Ch. 7).

A key factor in the success of IDs has been the large number of independent, owner-run firms, with constant experimentation and rapidly circulating information, all of which produced 'an environment favouring imitation of the right strategies and innovative change' (Bigarelli and Crestanello, 1994). At least at certain phases in the evolution of IDs, they have been extremely successful; that success is based mainly on the extent to which their structures facilitated rapid diffusion of innovations of all kinds. Although their industries are mainly LMT, and although there is very little R&D in IDs, there is a great deal of evidence of this innovation and its diffusion. The chapters on IDs in this volume add substantially to this evidence.

Porter (1990) is generally credited with having introduced the 'cluster' concept. Where a relatively large number of independent firms are located close to one another, and are involved in the same or associated industries, then that location is often called an industrial district. In general, IDs have smaller firms, more spatially concentrated, more tightly networked, more locally embedded and more industrially homogeneous than clusters. What Porter (1998) describes as the 'Italian leather fashion cluster' includes at least three different IDs. In other respects, however, there are many similarities between IDs and clusters. And some of the 'clusters' in Porter's (1990) book are identified by others as IDs (for example, ceramic tiles).

In the context of how and why knowledge flows among firms, the differences between IDs and clusters may not be trivial. Thus, for example, Porter's (1990) definition of clusters seems to privilege competition – 'strategy, structure and rivalry' – over cooperation as an element in the success of clusters. Lazonick (1993) uses extensive quotes from Porter (1990), particularly on the ceramic tile 'cluster'[10] in Emilia-Romagna, to show that what Porter sees as 'domestic rivalry' is really cooperation. Perhaps in response to these sorts of comments on his earlier work, Porter (1998) has since accorded greater weight to cooperation and trust. It might be argued that as Porter revised his views on clusters and their formation, the concept became more similar to that of IDs (Andreosso and Jacobson, 2005, 206). If cooperation and trust are factors in the diffusion of knowledge, then their absence would require other factors or mechanisms to facilitate the diffusion of innovations in clusters.

4.1 The Role of Knowledge Acquisition and Use in Technological Upgrading

As LMT industries are generally mature, it can be more difficult for them to innovate than it is for firms in high-tech settings. In contrast to high-tech industries, both the product and process spaces of LMT sectors offer fewer degrees of freedom for undertaking change. For example, products that are too innovative, such as stainless steel razor blades or radial tyres, can cannibalize existing markets and reduce sales, a problem that is not as prevalent among high-tech firms that offer products in markets in which they have not previously been involved. This reluctance of LMT firms to engage in more radical types of product innovation can in turn reinforce a tendency to rely on price competition that is also fostered by slow growth or stagnation in the sizes of markets for mature products, thereby bolstering a propensity to rely heavily on process innovation. Here again, the ability of LMT firms to engage in change is constrained, in this case because they have substantial fixed capital bases that generate knock-on effects when an alteration is introduced in one part of a complicated production system. To overcome these difficulties, LMT organizations require access to knowledge of a variety of types. As we have already argued, however, both developing and buying new knowledge can place severe strains on the small and medium-sized enterprises (SMEs) that account for the bulk of LMT firms. Not only is absorptive capacity expensive, but the other capacities in Figure 1.1 can also be costly in terms of time and money.

A major reason for the self-organization of firms into industrial districts is that closer contact with other firms offers superior access to the most important types of information and knowledge, including market intelligence and up-to-date technological know-how. It follows that in their early days the IDs that prosper are virtually by definition the ones that are technologically progressive. When districts mature, on the other hand, concentration on internal resources can lead to lock-in, stagnation and eventual decline if the best sources of innovation are now located outside the district (Grabher, 1993; Menzel and Fornahl, 2010).

Not all bits of information and knowledge are equally valuable, however. It is therefore useful to distinguish between a generalized cloud of facts and concepts that are 'in the air' for all who are willing to breathe in a Marshallian sense, and 'the News', Arthur Stinchcombe's (1990) term for what people really need to learn to solve specific problems. Districts that do not deliver the News cheaply are of less value to constituent firms that cannot afford to develop a full range of capacities (Figure 1.1) than are districts in which some degree of sorting is undertaken before information is released into the surrounding atmosphere.[11] This may not be a problem when IDs are very narrowly focused and at the technological frontier, but it gains in importance as districts mature and sources of the News are increasingly located externally. When this happens, the value that derives from face-to-face contact (what Storper and Venables (2004) call 'the Buzz') diminishes and firms in IDs are encouraged to break down barriers between their immediate districts and possible external sources of knowledge.

In order to survive in a deteriorating situation, firms operating within IDs have various choices depending on how their new environments are evolving. One example, which is also discussed in the section on globalization, is the Belluno eyewear district (Campagnolo and Camuffo, Chapter 6 in this book), where successful firms in the ID have changed strategy to become part of larger, even global, manufacturing and marketing networks. This has allowed firms from the ID (or at least the firms that survive) to exploit their remaining areas of comparative advantage while outsourcing other operations to suppliers chosen on the basis of competence rather than geography.

In addition, in recent years, the hermetic nature of many districts has been potentially undermined by improved information and communications technologies (ICT) and faster transportation networks. While these factors are not equally relevant to all districts, or to all firms within a given district, they have opened the possibility of broader sets of relationships for particular firms. Geographically isolated companies that were formerly locked into dealing with their neighbours because of high search costs can now use the internet to find new suppliers who might offer better deals, or to get real-time information on consumer tastes. Although the data they uncover may not initially be as accurate as they can obtain through face-to-face contact (Hall, 2001), search engines allow even small firms to establish better benchmarks for negotiating with traditional suppliers in their own vicinities. On the other hand, firms need to develop new knowledge management techniques if they are to exploit these new possibilities.

In the past, smaller companies operating in IDs relied on larger 'leading firms' to connect them with the wider world. Typically, leading firms were assemblers that brought together inputs from the small specialist firms in the district and then marketed them to outsiders. Because of their size, they could afford to attend international trade fairs and make other types of contacts that were not feasible for smaller producers. Their external links gave leading firms access to new information and knowledge on changing consumer tastes, improved machinery and other areas that could then be distributed throughout the ID (Rychen and Zimmermann, 2008). But the effective establishment and maintenance of a range of innovative and desorptive capacities (Figure 1.1) entail extensive investments to facilitate the understanding and communication of new knowledge and information. This is especially true of knowledge whose tacit aspects must be codified to achieve widespread dissemination (Morrison, 2008).

As a result, leading firms are increasingly becoming 'knowledge gatekeepers' because they may have limited incentives to encourage spillovers of knowledge in which they have invested heavily. In a companion piece to Chapter 7 in this volume, Morrison (2008) has found that leading firms in the furniture industrial district around Murge in southern Italy are quite selective about how they distribute knowledge acquired externally to other firms in the ID. While they are relatively willing to share information, which is often equivalent to raw data, they are reluctant to give others access to knowledge, which is information that the gatekeepers have themselves processed and codified. The reason for this different behaviour is that the gatekeepers expect to gain competitive advantage from their investments in innovative capacity and want to limit their spillovers unless they can get something valuable in return (Morrison, 2008). In this sense, new ICT and related new process technologies such as cad-cam may reduce the ability of smaller firms to gain access to 'the

News' by increasing the incentive of leading firms to engage in expensive codification, in the process devaluing less differentiated forms of Buzz and of information that is in the air.

However, Morrison does emphasize the commitments made by many firms, particularly the larger ones, to acquiring knowledge from outside the Murge district and to innovating (Chapter 7 in this volume). He shows that most medium size and large firms in the district have hired technically-trained personnel and have made substantial investments in absorptive capacity through their R&D and engineering activities. This has allowed them to cooperate extensively with suppliers, agents and clients and, in a number of cases, to participate actively in the development of important new machinery.

In Chapter 3, Fiorenza Belussi, Silvia R. Sedita, Tine Aage and Daniele Porcellato investigate the knowledge flows in two contrasting industrial districts in northeast Italy. On the basis of detailed mapping of flows in the Loria horticultural district and the sport system district of Montebelluna, they conclude that the appropriate modes for gathering and analysing information and knowledge depend heavily on contextual factors. In Loria, where firms are commonly small and the bulk of important information and knowledge comes from outside the district, gatekeeper mechanisms are used because most local firms do not have the resources to absorb and configure information themselves. Firms in Montebelluna, however, rely much more on local face-to-face contact because the district is a world leader and internal generation of knowledge is more important than importing it from outside. In general, their conclusions are consistent with earlier findings on the importance of firm size and on the effects of a district's position in the technological hierarchy for the organizational form of the district.

Other chapters in this volume examine different approaches to knowledge acquisition and use. In Chapter 2, José L. Hervas-Oliver and José Albors investigate a range of knowledge sources based on a sample of eight districts in four industries in the Valencia region of Spain and in Italy. Their aim is to test the applicability of the Resource-Based View to studies of industrial districts.[12] In particular, they assess whether the presence or absence of higher-order capabilities, which are external to individual firms but presumably available to everyone within a region, affects levels of firm performance. The higher-order capabilities that Hervas-Oliver and Albors discuss permit firms to gain access to important knowledge but they are not just 'in the air'. Instead they are all definable and measurable, and include the size of the local skilled labour force, linkages with suppliers and competitors, and linkages with universities and research institutions. They also investigate the importance of absorptive capacity among firms and the value of leading firms in improving performance within clusters. Their overall finding, which is based on a wide range of evidence for each of the case studies, is that the higher-order capabilities that they have identified have a substantial effect on firm performance. With the exception of ceramics, where the Valencia Region is well endowed, Spanish low-tech industries suffer from a lack of higher-order capabilities in comparison to counterpart industries in Italy. In other words, firms do benefit when efficient mechanisms for transferring knowledge from outside are readily available to complement and supplement their internally-generated knowledge. Although Hervas-Oliver and Albors find that the presence of leading firms is beneficial, however, they are unable to trace their internal and external connections in detail as Morrison (2008) and Belussi *et al.* (Chapter 3 of this volume) have done.

In some cases, local institutions have taken over from leading firms and gatekeepers in spreading knowledge throughout an ID. As described by Diego Campagnolo and Arnaldo Camuffo in Chapter 6 of this collection, firms in the well-established eyewear district of Belluno in the Veneto now follow a diversity of strategies. A few larger firms have increasingly absorbed their subcontractors and become vertically integrated on a global scale. Even though they continue to draw on some locational benefits such as easy availability of relevant skills, they have in effect abdicated their positions as leading firms and are not heavily involved in disseminating knowledge to their neighbours. This role is now undertaken by a collection of local institutions, many of which are public or semi-private agencies that provide knowledge intensive business services (KIBS) to the remaining small and medium sized firms. Because they are in close touch with eyewear firms in the district, these institutions are aware of what firms need to know as well as of their weaknesses. They are consequently well-placed to provide up-to-date knowledge on product and process technologies and other areas that are beyond the absorptive capacity of individual small firms. Local institutions also supply quality certification for SMEs operating in international markets. As providers of knowledge, the institutions have therefore filled an important gap created by the vertical integration strategies of larger firms and enabled many of the remaining small firms to remain viable.

In their discussion of the electric guitar industry in Chapter 8, Thierry Rayna and Ludmila Striukova show how local knowledge sources can become irrelevant in the face of thorough-going product innovation. Gibson, originally a well-known producer of acoustic guitars, operated in the small luthier district of Kalamazoo, Michigan. Because skilled workers were available in the vicinity, Gibson had an incentive to retain many of its traditional manufacturing techniques when it also began to produce electric guitars following World War II. The founder of Gibson's major competitor, Leo Fender, was an electronics technician in Fullerton, California, an area not known for producing stringed instruments. Fender was not only unaffected by a personal legacy as a guitar maker, but could not match Gibson in access to skilled luthiers. At the beginning of their period of competition, when both firms were trying to produce electric models that resembled acoustic guitars, Gibson therefore had an edge, but this dissipated within a few years as one of the major features of acoustic guitars – their hollow bodies – was abandoned in favour of solid body models. This undermined the value of being part of an ID by reducing the scope for luthier skills. Instead a premium was placed on perfecting an essentially new instrument that catered to a different group of musicians. New knowledge was still needed, a great deal of it, but as producers of an innovative product, Fender and Gibson found that their internal technical skills could be well directed, when they bothered to pay attention, by users who offered suggestions to refine the capabilities of the instrument (von Hippel, 1988, 2005).[13]

A final important need faced by all LMT firms that innovate is to blend old and new technologies as effectively as possible. As we have already pointed out, the existence of an efficient asset base tends to introduce rigidities that impede subsequent innovation. When performance has been optimized for a collection of physical assets, changes to any individual component can cause major problems by disturbing the relationships between machines. The best known example of this is perhaps Henry Ford's River Rouge Plant, which had to be shut for many months and gutted when Ford switched from the Model T to the Model A in the late 1920s (Hounshell, 1984), but there are numerous examples stretching back even earlier (Pollard and Robertson, 1979, Ch. 6). One of the advantages of codification (Morrison, 2008) is that it eases modifications to older assets and increases the chances of achieving compatibility when new equipment is introduced piecemeal into an ongoing system.

In more extreme cases, bringing technologies of different vintages together can affect the whole structure of an ID. Lorenzo Ciapetti investigates the reorganization of entire knowledge bases generated by the introduction of a new type of hybrid product on top of an existing, already sophisticated product line. In Chapter 5, he demonstrates how the creation of 'mechatronic' devices (Freddi, 2009) has transformed important aspects of the operation of the traditional mechanical knowledge base in the Reggio Emilia district of the Italian province of Emilia-Romagna. Mechatronic firms, which are a subset of the machinery ID, must master aspects of electronics and IT that were not important (indeed, were not even developed) during the early decades of the district's success. This has not destroyed the existing district based on machinery manufacture – only about a third of total district production involves the use of electronic controls – but it has altered the potential of the district by superimposing a highly complicated set of technologies from outside on the longstanding knowledge base. This has entailed improved overall absorptive capacity and achieved better coordination of design and engineering efforts through expanded innovative capacity (Figure 1.1). It turn, this may be expected to lead to further increases in sophistication in other types of machinery produced in the district. As a result, a traditional ID has opened a significant path to renewal.

4.2 Globalization and the Transformation of Industrial Districts

Real-world clusters and, in particular, IDs have in some cases undergone so complete a transformation as to no longer be identifiable as IDs. This is not to say that there was not always variety among IDs. In fact few were consistent with all the characteristics of the 'canonical' ID. But the variety has increased and globalization in particular has challenged the traditional ID structure.

For many of the districts discussed here, globalization equates simply to increased international competition in industries that in the past have tended to rely on local or national markets.[14] A number of factors have contributed to this trend in recent decades. Reductions in tariffs and other trade restrictions are an obvious example, but changes in patterns of technology diffusion have also been important. Knowledge that was once thought to be path-breaking, as in the automobile industry, has now become codified and mundane in a literal sense. Similarly, improved mechanization has eroded the need for skilled labour in some industries. Increased mechanization has also led to increases in the minimum efficient scale of output in some cases, making it harder for small producers to remain competitive. Most importantly, perhaps, changes in ICT and in transportation have made it cheaper and easier for firms to do business with suppliers and customers from further afield than was feasible until the 1990s. Taken together, these developments have had mixed results for industrial districts in Europe because, while the viability of some firms has been undermined, in other cases increased access to markets has facilitated expansion for firms with the resources and flexibility to take advantage of new opportunities.

Naturally, going global has not been a viable strategy for all firms in all IDs. In some cases, the final output has not been important in international markets. Alternatively, specific locational advantages such as the availability of raw materials may tie production to particular regions.

Or, very commonly, firms have been too small to afford to enter global markets on their own. Nevertheless, there have been significant developments. Jacobson and Garibaldo (Chapter 4 in this volume) use Storper's (2000) framework, combining embeddedness into the local economy (territorialization) and globalization (international flows in the production system) to consider the direction of change among relatively small firms in LMT sectors. What their results suggest is that these firms in general have had to respond to globalization but that how they do so varies. Some have reduced their local embeddedness; in such cases it is likely that similarities to the canonical IDs have declined. In other cases firms have utilized the aspects of their locality to maintain and enhance their international competitiveness. Even in such cases, there is usually an intensification of interaction with suppliers and/or customers in other countries. One broad conclusion from their chapter is that non-spatial proximity is increasingly important in diffusion of innovation.

Two other chapters illustrate aspects of globalization on firm behaviour and the structure of IDs. The expanded range of knowledge linkages that Morrison (Chapter 7 in this volume) has found derive largely from an expansion into international markets of larger firms in the Murge sofa cluster since the early 1990s, allowing them to draw on a wider and more diverse set of customers, agents and suppliers. Similarly, Campagnola and Camuffo (Chapter 6 in this volume) show in detail how the eyewear industrial district was transformed, through cost competition from China, into a large-firm dominated industrial sub-sector. They show, moreover, that information about market response to product innovation was crucial. This was not originally available to the ID, but has become available both through the growth of a small number of large firms with distribution networks in Europe and abroad, and local associations of firms, unions and local authorities. A conduit has been created, providing information from the market and facilitating product innovation (design) to respond to that information. As a result of these successes, while many of the small firms in the original ID have closed, many others have survived, and grown, by adopting a variety of innovative strategies. The Belluno district is arguably now more like a cluster than an ID, at least in part as a result of globalization.

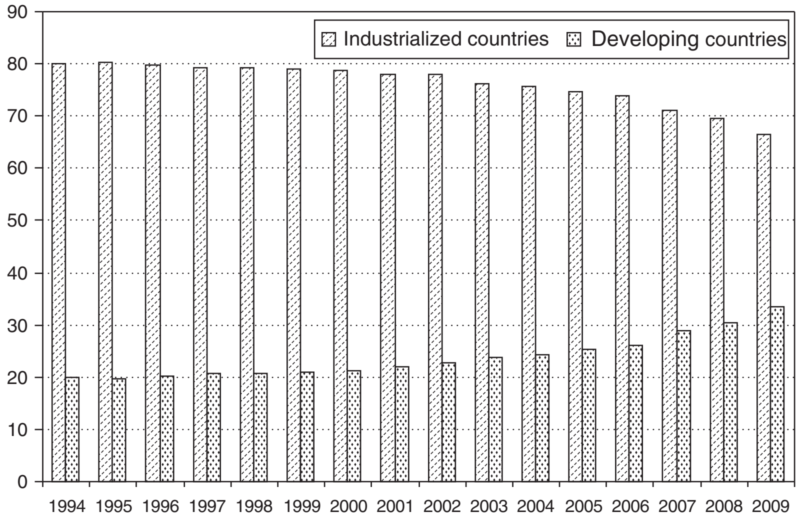
5. DIFFUSION IN DEVELOPING ECONOMIES

The effects of globalization for LMT sectors in newly industrializing countries (NICs) have also been substantial, but the outcomes for knowledge acquisition and usage are not necessarily symmetrical with those in the already developed nations studied in Chapters 2–8. While the opportunities for manufacturers in Western Europe, Japan and North America have often been adversely affected by globalization, firms in the developing world have sometimes been able to gain easier access to technological knowledge through membership in global value chains. This has not always proved fatal to developed country firms, and has even led to increased strategic flexibility, as in the Belluno eyewear district, but it has nonetheless accelerated the ability of firms in NICs to catch up with industry leaders when other circumstances are favourable.

Improved ICT and changes to institutional arrangements, as well as globalization, have altered the nature of economic development in recent years. In particular, the role played by manufacturing has changed considerably. Industries that were regarded as central to the prosperity of wealthy nations in the decades following World War II have lost their primacy to rapidly expanding service activities. As a result, manufacturing has been allowed (and in some cases encouraged) to migrate to regions that, until recently, were believed to lack the skills and knowledge needed to undertake modern production. The result has been a trend towards economic convergence with developed nations on the part of a limited number of countries, mostly in East Asia, and a reappraisal of the role of knowledge diffusion in economic development.

Although early development economists such as Rosenstein-Rodan (1943) had looked to investments in manufacturing to lead development,[15] they were soon countered by others, including Nurkse (1953) and Lewis (1954), who contended that development based on small segments of the economy would lead to bottlenecks because of failures in both demand and supply. They advocated 'balanced growth' across many sectors that would reduce the chances of dualism, in which development was confined to a narrow slice of the economy while the majority of the population remained trapped in traditional low productivity industries. A few years later, however, balanced growth was attacked by economists such as Hirschman (1958) and Rostow (1960a, b), who argued that development could be achieved best through concentration on one or a few favourably placed 'leading sectors' whose success would, through backward and forward linkages, stimulate growth and modernization in a range of other industries. The debate has been further complicated by political considerations as governments and international bodies have deliberated over the value of allowing foreign direct investment (FDI) and weighed the possible advantages of growth based on domestic demand versus an emphasis on exports.[16]

In view of the very different context in which they were working, it is unlikely that the economists of the 1950s envisaged the course that



Note: MVA = Manufacturing value added.

Source: UNIDO (2010).

Figure 1.2 Share of industrialized and developing countries of world MVA 1994–2009 (%)

development has followed in the past 20 years. They were understandably unaware that services would replace manufacturing activities as the main activity in wealthy economies, which has led to increased willingness (but not eagerness) to surrender well-entrenched industries. Moreover, they underestimated the time lags involved in translating knowledge transfer into economic transformation. Nevertheless, in the last two decades, developing economies have gained increasing shares of the world's manufacturing output (Figure 1.2). Since around 2000, following a long period of stability, the share of NICs in global manufacturing value added has risen from 20 per cent to well over 30 per cent in 2009. Moreover, the growth has not been choked off by the global financial crisis but has accelerated in recent years. Nevertheless, the probable contribution of the increasing migration of manufacturing activities to economic development remains unclear. In the short run, increased manufacturing activity almost certainly contributes to development. Even if the industries concerned are fairly primitive by the standards of wealthy countries, they are usually more sophisticated than those already established in the developing world because they offer higher rates of productivity and generate improved knowledge and skill bases in local populations. In the longer run, however, it is not at all clear that this will lead to a 'take-off into sustained growth', as Rostow (1960b) contended, because in a technologically dynamic world this would require further learning. In order to avoid being relegated permanently to supplying goods that are now seen as leading to dead ends in wealthy economies, manufacturers in NICs need to learn faster than competitors in the developed nations – to get closer to the technological frontier or even to shove it outwards themselves.

Vernon's (1966) argument about the international shifts of production arising from the product life cycle was more optimistic about development in poorer countries because it suggested that leading companies in the developed world would lead this process. First, they would set up in less developed countries, when production was standardized, to exploit lower production costs. Second, this would increase the level of sophistication of production and organization and, over time, transfer technologies to the local economy. However, in the 1970s, after decades of largely unproductive development experiments following World War II, it was not at all obvious that developing nations would be able to catch up substantially. With the exception of Japan – which had already achieved high levels of manufacturing expertise before its economy was destroyed during the war – and of the Soviet Union, no country had substantially improved its relative economic position in the twentieth century, and the range of developed nations remained largely confined to Western Europe and North America. In the 1980s and 1990s, however, the rise of the Asian Tigers (Taiwan, Korea, Singapore and Hong Kong) led to renewed optimism about the ability of nations to rapidly increase their productivity and standards of living. But when analysed in terms of earlier debates among economists, the sources of development remained murky. Some Tigers, notably Singapore and Hong Kong, had based their growth on export markets and FDI, but the much larger South Korean economy was able to mount a similarly successful development campaign primarily on the basis of domestic markets and domestic investment. Even the prospect of economic dualism has not (so far) been a barrier to development in highly populated China and India, where initially small proportions of people with middle-class incomes were nevertheless sufficiently numerous to spark world-scale industrialization (Hobday, 1995).

The continued success of developing economies in South and East Asia will depend on major changes in both corporate and government strategies that facilitate their ability to upgrade their knowledge bases.[17] The creation of absorptive capacity even in developing economies has always had a substantial indigenous component (Robertson, 2003), but catching up when levels of knowledge are closer to the frontier requires even more local learning as firms must be able to develop skills in R&D as well as higher degrees of tacit knowledge in process engineering.[18] When firms in NICs make their own forays into unexplored territory, as is happening increasingly, their approach to learning must be even more proactive.

On a theoretical level, many of the issues confronting firms in developing economies that attempt to use LMT industries as springboards for catching up are comparable in kind, if not in degree, to the dilemmas associated with knowledge diffusion in the developed world. To gain and retain competitive advantage, however, these firms need to follow their own strategies, augmented by access to inventive, transformative, innovative and connective capacities (Figure 1.1).[19] In practice, the contexts in which firms in developing economies operate are far different from those faced by firms in wealthier nations now and at similar stages in their own histories.

Depending on circumstances, it is possible that late-comers face less trouble in integrating old and new capital equipment than older firms, if only because they may have been able to purchase entire sets of the latest equipment at the outset of their operations. This is more likely to be true of firms financed by overseas capital, however, than of cash-strapped locally owned firms dependent on second-hand machinery. In addition, there is no need for firms in developing nations to repeat each stage of the learning undergone in the past. As knowledge can be acquired at its most modern stage, steps may be skipped, allowing for relatively rapid catch-up if conditions are otherwise favourable (Lee and Lim, 2001). However, an ability to tap into the latest learning is more realistic for codifiable than for tacit knowledge. Perhaps paradoxically, therefore, expense aside, R&D activities may be more easily within the grasp of firms in developing countries than are vital day-to-day technical activities as well as aspects of business organization that need to be worked out on the basis of experience (Liagouras, 2010).

In his discussion of the learning strategies of LMT firms in Taiwan (Chapter 11 in this volume), Liang-Chih Chen argues that technology transfer in NICs whose societies value education is relatively easier in high technology sectors because it relies more heavily on skills that can be learned in the classroom. This, he contends, is less expensive than acquiring expertise in production engineering, which involves more learning-by-doing. In addition, the processing of catching up may be eased when there are technological discontinuities because LMT firms in developing economies can adopt new techniques and machinery nearer to the start of their life cycles, reducing any deficits in learning-by-doing that they encounter when following foreign firms that have already mastered older technologies. This can be especially useful if the new technologies allow firms in less developed economies to sidestep facets of established technologies that had been particularly troublesome. For example, by adopting CNC (computer numerically controlled) technology, Taiwanese machine tool firms were able to use electronic components to overcome some of the mechanical problems that had afflicted older models.

Chen contends that many of the learning processes of LMT firms depend on possessing a core of trained technical personnel to provide both absorptive and transformative capacity. Learning-by-imitation, for example, is not a passive activity but depends on thorough technical knowledge in order to engage in reverse engineering. Equally, deciding which new equipment to purchase and recognizing opportunities that are 'in the air' depend on an ability to make informed decisions. Institutional arrangements such as clustering and the presence of government research agencies can assist technology transfer, but in the end success requires good technical judgement at the level of the firm.

The essay on the evolution of the Chinese electronics sector by Guo Yung-Hsing (Chapter 9 in this volume) illustrates several of the points we have made. As it has been the source of repeated technological breakthroughs since the late nineteenth century, the modern electronics sector is a hybrid – a mixture of technologies of various vintages, many of which are long-established and well codified while others are new and exotic. The industry therefore offers a wide range of possible strategies for manufacturers. They may target older products with proven process technologies or innovative goods whose product and process technologies are still under development; they may emphasize producing for their domestic markets or become exporters; they may be assemblers or manufacture their own components; they may manufacture only simple components, outsourcing more sophisticated items, or they may also manufacture higher-tech and more capital-intensive components; or they may undertake a combination of these strategies. Since the 1980s, Chinese electronics firms have moved on balance towards higher-end strategies, in the process gaining ground on, although not yet catching up with, overseas competitors. These developments were heavily influenced in the 1980s and 1990s by changes in policies on foreign exchange and foreign investment. When restrictions were eased, overseas firms, many of them Japanese, brought knowledge and skills that have slowly spread to indigenous producers. In addition, in the early stages, Chinese firms were hampered by a shortage of process engineers, as Chen discusses for Taiwan. This largely restricted them to manufacturing simple items such as fans, or to assembling more complex products – colour televisions, refrigerators and air conditioners – with components that were either imported or produced locally by foreign-owned firms. Since the turn of the century, however, larger

Chinese firms have been moving increasingly into assembling flat panel television screens, compressors and other kinds of advanced components.

In Chapter 10, Vicky Long and Staffan Laestadius investigate the next stage of development. Through a collection of case studies based on the establishment of laboratories for ICT research in Sweden, they show how Chinese producers of mobile phones and related products have been able to move from the low-tech end of operations, relying on cheap inputs to build low-cost products, to positions at or near the technological frontier. As in the case of the electronic appliances that Yung-Hsing examines (in Chapter 9), ICT equipment mixes components of different vintages. As a result, Chinese producers initially had opportunities to enter manufacturing at a relatively low level of complexity. Their ability to advance quickly, however, is at least in part attributable to the fact that the global industry is still evolving rapidly as telecommunications equipment moves from generation to generation. As Chen has noted, because of its reliance on science and codification, high technology development is not as challenging to firms in NICs as are fields more dependent on long experience and tacit knowledge. Progressive Chinese firms have taken advantage of the availability of PhD level scientists in China – and of the willingness of non-Chinese scientists in overseas countries to work for Chinese firms – not only to acquire the latest knowledge on ICT but to contribute creatively. This helps to negate failings in process engineering as no firm anywhere has yet mastered all of the new production techniques, and allows Chinese firms to build on their substantial domestic markets to become notable exporters.

The chapters by Yung-Hsing and Long and Laestadius also confront fears that economic or social dualism may ultimately choke off modernization. At least in very large countries such as China and India, the presence of large numbers of relatively poor consumers can become a challenge (Prahalad, 2004) to firms that have already been successful at the more expensive end of the market, encouraging modifications to products and improvements in process engineering to increase affordability among huge masses of potential consumers.

The final two chapters in this book further illustrate the importance of contextual and strategic factors for performance. In Chapter 13, Saon Ray uses a total factor productivity model to investigate the determinants of growth in a wide range of Indian industries of varying levels of technological sophistication. His econometric results show that a large and diverse assortment of factors underlies productivity growth across sectors. Although there are different patterns when sectors are divided into high, medium and low technology groups, the outcomes are far from uniform. Overall, his findings suggest that there may be merit in the contention of

Kirner *et al.* (2009) that traditional classifications of levels of technology mask different levels of technological behaviour by firms within each class – for instance, that some firms in low-tech sectors may have medium- or even high-tech characteristics, or that some firms in high-tech sectors may not meet high-tech standards.

In Chapter 12, Ali Fikirkoca, Behar Çelikkol Erbas and Arcan Tuzcu present results from a study of regional innovation systems in Turkey. Although they do not identify industrial districts as such, they are able to measure important influences on innovation in LMT sectors in eight geographical regions in order to assess the possible consequences of imposing European Union regional policy if Turkey's bid to join the EU succeeds. They conclude that regional and national sources of knowledge are more important than international ones in promoting learning, perhaps because internationally successful local firms may act more successfully as conduits of external information than foreign-owned firms. As the knowledge capacities and management skills of many Turkish firms are weak, they seldom use knowledge-intensive business services, including banks and consultants. Instead, government agencies help small firms to hook into international knowledge networks as well as providing financial support. To the authors' surprise, reported levels of innovation are relatively low, even by Turkish standards, in the large regions of Istanbul and Ankara, but this may be due to sampling errors.

6. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

Taken together, the chapters in this book present a complex picture of knowledge transfer in LMT sectors. Important knowledge sources identified by the contributors include, among others, suppliers, customers, competitors, universities and other training institutions, and government and private agencies. For firms in industrial districts, both internal and external sources are used, while firms in NICs draw on domestic and foreign sources. The chapters strongly suggest that, as a result of improved and relatively cheap ICT and of globalization, knowledge is more widely accessible than it was twenty or thirty years ago, even for small companies in industries such as furniture manufacturing that are normally classed as being low-tech and close to stagnant.

The case studies could also be taken to indicate that the routes chosen for knowledge transfer in LMT industries are basically contextual as firms employ (or fail to employ) sources depending on the problems they face and the solutions that are cheaply and quickly available to them. Detailed problems often differ from firm to firm depending on factors such as the installed capital base. Furthermore, as the way in which problems are perceived depends on the mindsets of individual managers, it is reasonable to expect that a variety of options would be explored for challenges that, to outside observers, seem nearly identical. This divergence in responses is heightened by the extent to which solutions are accessible in different environments. Owing to reduced trade barriers as well as improved ICT and transport, accessibility has increased substantially in recent decades, and this can be expected to continue in the future as greater attention is given to improved codification of digital information and better search engines. But while these will make it easier for problem holders and solution holders to come into contact, they could also undermine intellectual property rights. Some artificially imposed limitations on knowledge flows might therefore be expected.

One interesting aspect of the findings of the contributors is the relatively small role assigned to government in both developed and developing economies. Despite the input of government agencies in Spain, Italy, Taiwan and China, the involvement of governments in improving knowledge usage is relatively minor. Instead, even in Communist China, the major thrust for change comes at the level of the firm. Governments are shown to play a generally passive role in knowledge diffusion and quality certification while entrepreneurship within firms supplies the insights that guide achievement. It is unclear, however, if this reflects a necessary limitation on the scope of governmental activity or if better targeted policies could achieve more.

Although the research presented here has usefully uncovered the variety of sources that LMT firms can draw on for knowledge, even if the list is incomplete, it leaves many questions unanswered. In the picture we have exposed, knowledge seems to flow much like water, sometimes totally blocked but often taking alternative but longer paths when confronted by obstacles. It is reasonable to ask whether the obstacles might not be removed, or tunnelled through, allowing the paths to be straightened so that search costs and the time needed to innovate might be reduced. To some extent, we have seen that this is already happening as a result of improved ICT, but other improvements could be possible. This brings us back to one of Marshall's major preoccupations – the role of interpersonal contacts in encouraging and facilitating knowledge flows. Search engines are likely to remain blunt instruments in order to preserve intellectual property rights and commercial confidence. They are also unlikely to replace the pub as spots where ideas are spontaneously generated. On the other hand, e-mail and inexpensive telephone calls are useful in allowing ideas to be exchanged, and when combined with television links they can help to undermine barriers imposed by tacitness.[20] This points to the possibility of virtual districts without geographical limitations, but the question of how to make the initial connections remains open. At this stage, when cyber networks are still largely experimental, research into knowledge diffusion could usefully investigate ways of constructing systems that will make good use of new ICT by identifying ways of setting up connections while keeping spillovers within acceptable limits.

A further area for future research is to find ways of improving the management techniques needed to make efficient use of new knowledge at the firm level. This requires operations on two levels. The first, establishing connections between firms, has already been noted, but better management of new knowledge within firms is also needed. Deeper investigation of ways of developing knowledge capacities and dynamic capabilities by firms of all sizes could lead to substantial payoffs. Recommendations must recognize, however, that knowledge management needs vary among firms (a point well illustrated in this book) and that solutions need to be indicative rather than prescriptive.

NOTES

1. Better economic performance includes the more efficient use of physical inputs such as fuel and raw materials as well as higher levels of output. Over many centuries, for example, innovation has led to very substantial savings in fuel usage per unit of output (Smil, 1994, 2005 and 2006).
2. This figure differs from the original in Lichtenthaler and Lichtenthaler (2009) in that (a) transformative capacity has been added to connective capacity in the external knowledge transformation box and (b) a number of feedback arrows have been added to make the model non-linear.
3. For more on LMT industries, see Hirsch-Kreinsen *et al*. (2006), Sandven *et al*. (2005), Tunzelmann and Acha (2005) and Robertson and Patel (2007), as well as the contributions to Hirsch-Kreinsen and Jacobson (2008) and to the special issue of *Research Policy* (2009) entitled ‘Innovation in low- and medium-technology industries’.
4. Although they may fluctuate greatly, as in Ireland, where producers of construction materials grew rapidly during the construction boom in the country’s Celtic Tiger phase.
5. Product innovation is not always neglected, as Rayna and Striukova show in their discussion of the development of the electric guitar in Chapter 8. It is indicative of the uncertainty surrounding innovation processes that, although the application of electric amplification was originally intended to be an incremental improvement to acoustic guitars, it inadvertently led to the creation of a very different instrument that served a separate niche in the music industry rather than replacing traditional guitars – a change that the manufacturers not only did not intend but did not even recognize until it had become well established among users.
6. Although Lichtenthaler and Lichtenthaler (2009) refer to transformative capacity as a tool to manage internally generated knowledge, it is also needed to ensure that knowledge that has been acquired externally or is a mixture of internally and externally generated knowledge will not be lost.

7. For a large collection of recent contributions, see Becattini *et al*. (2009).
8. Ellison *et al*. (2007) interestingly see all three advantages in terms not of externalities, but of reduction in transport costs. The first advantage is a reduction in the transport cost of ideas, the second of goods and the third of people.
9. This paragraph draws heavily on this source.
10. The ceramic tile system is identified by virtually all other scholars as an ID.
11. As Owen-Smith and Powell (2004) point out, the idea that knowledge or information may be equally distributed when barriers are low or non-existent is often a delusion because different types of comprehension may be needed to make sense of different facts or concepts. As a result, specialized communities of practice within an industrial district may gain control over some knowledge because only they know how to interpret it.
12. They explicitly use the terms 'industrial district' and 'cluster' interchangeably.
13. Not that either firm made the best possible use of information from leading users, although Fender was somewhat better than Gibson at listening and acting. See Rayna and Striukova, Chapter 8 in this volume.
14. The districts discussed here have not been substantial recipients of foreign direct investment, nor have takeovers by foreign firms been important.
15. As used here, economic development involves more than growth; it also includes modernization as sectors of increasing technological sophistication expand faster than the economy as a whole.
16. The literature on globalization and related topics is enormous and growing rapidly. For an introduction, see the following works and the references cited therein: Wolf (2004) and Bhagwati (2004); Chang (2003); International Forum on Globalization (2002); Stiglitz (2002). For an approach to globalization most congruent with the industrial and agglomeration approach of the present volume, see Dicken (2007).
17. As early as the 1990s, some East Asian firms were achieving success in high technology electronics sectors (Hobday, 1995; Mathews and Cho, 2000).
18. Amsden (2001, Table 1.2, p. 4) analyses three types of 'technological capabilities': (1) production capability; (2) project execution (investment capability); and (3) innovation capability. The last refers to acquisition of knowledge needed for radical innovation, such as pure science and basic, applied and exploratory research, which she in effect privileges above the knowledge needed for incremental development in mature industries (project execution). Our contention is that both types of knowledge are ultimately needed for development, but that (what she terms) project execution is central in the early stages and also continues to be of overwhelming importance for success in later stages of development.
19. This does not imply that each firm needs to generate all of the capacities independently. In some cases, they may be developed collectively, as is discussed in several of the chapters in this volume (for example, those by Hervas Oliver and Albors (Chapter 2), Belussi *et al*. (Chapter 3), and Campagnolo and Camuffo (Chapter 6)). Individual effort is still needed, however, to tap into capacities made available by local institutions.
20. This example also shows the dangers of electronic communications and why they may be used sparingly. Televised instructions can now be recorded by the recipients and opportunistically sent on electronically to third parties, creating spillovers that erode the value of the knowledge held by the senders. This would have been more cumbersome and expensive when communications were more primitive and a need for face-to-face contact would have limited the geographical scope of leakages of knowledge.

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