1. Introduction

Franco Malerba and Richard R. Nelson

1.1 INTRODUCTION

This book examines the processes of technological and organizational learning in five different economic sectors: telecommunications, pharmaceuticals, software, semiconductor and agro-food, in several different developing countries: China, India, Brazil, Korea, Taiwan and others. The chapters presented here are part of a larger programme of studies – the Catch-up Program – concerned with the examination of a range of variables affecting the ability of countries behind the technological and economic frontiers to 'catch up' with the leaders, in particular the roles of indigenous and multinational firms, and of non-firm actors like universities and public labs, how IPR regimes affect catch-up, the government policies that are effective in supporting catch-up, and other important variables.

The five sectors examined in this book represent a wide range of cases according to various classifications. They include a science-based sector: pharmaceuticals; two sectors where product design and engineering are important for competitiveness: semiconductors and telecommunications; a service sector of a specialized supplier type: software; and a traditional sector: agro-food.

The evolution of these sectors has been examined in a variety of different countries, ranging from those that started their catching up quite early (such as Korea and Taiwan), to those which are now becoming major protagonists of economic development (such as China and India). These countries differ very much in terms of size of domestic market: in some of these countries (such as China, India and Brazil) the size of the domestic market has been a major target for firms, while in others the internal market is small and exports have played a major role.

In several cases the sectors examined in this book have been major drivers of the economic growth of a country. This is the case for pharmaceuticals, semiconductors and telecommunications in the developing countries where these sectors have taken hold. These sectors have been development drivers in several senses: the relatively high-income employment that they generated, the amount of capital investments required, and the knowledge spillovers that have affected other sectors. Some of these sectors have vertical linkages with other sectors within a country: think of telecommunications and software, agriculture and the food industry, semiconductors and machine tools and computers.

Other books on industrial economic development have either focused on a specific industry in a specific country (see for example Amsden and Chu, 2003; Breznitz, 2005) or, when they have examined different sectors, they have considered each of them in a different country (Chandra, 2006; Malerba and Mani, 2009). This book takes a different perspective: it analyses the evolution of several industries, each of them examined in several countries.

The reason for this orientation is that we want to examine the differences, as well as the similarities, of what is required for catching up in different economic sectors. The nature of the technologies used differs significantly across economic sectors, as do the nature of the customers, and the kind of competition indigenous firms face, and hence the needed skills and appropriate forms of firm organization and management. Industries differ significantly in the extent to which they need to draw on universities for the skills and knowledge they need in order to be competitive, and in the kinds of government policies needed to support them. Countries differ in the extent to which they can provide the broad background conditions for the development of different industries. Because of these differences, we believe that analysis of the processes involved in economic development requires a detailed and fine-grained analysis of the interplay between sectoral factors and country-level factors.

Before entering into the core of this book, we need to briefly discuss what we mean by the term 'catch-up'. The term has been used in macroeconomics in analyses of the extent to which the growth of income per capita of different countries significantly behind the frontier at the start of the time period enabled them to 'catch-up' with the leading countries in that dimension by the end of the period. However, in characterizing the development of particular economic sectors, as we have noted, we believe it is important that the description and analysis be relatively fine grained, which calls for a somewhat more flexible and qualitative conception of catching up. Once one looks at sectoral economic development in detail, one can recognize that each country does things in a somewhat different way. Product mixes differ. Industrial structures vary. Often the markets served vary.

However, if interpreted broadly, the concept of catching up still seems a useful one for thinking about economic development at a sectoral level. In all of the sectors considered in this book, much of the learning of firms in developing countries involved learning about what firms at the frontier were doing. And the higher performance of firms at the frontier provided both a model and an aspiration for efforts of firms behind the frontier to improve their performance.

This introductory chapter is organized as follows. In section 1.2 we discuss the basic orientation of the broad 'Catch-up Program'. In section 1.3 we argue for the importance of analysis at a sectoral level, because there are significant differences across economic sectors in the variables and mechanisms involved in catch-up. It introduces the notion of sectoral systems and identifies the main sectoral variables used in the following analysis. In section 1.4 we introduce the five sectors and lay the ground for the following analysis.

1.2 ECONOMIC DEVELOPMENT, CATCH-UP AND INNOVATION SYSTEMS

In the following pages we briefly review the basic analytical orientation of the Catch-up program (see Nelson et al., 2005 for a more in-depth discussion). Economic development involves deliberate efforts to catch up, in the sense that economic and technological practice in leading nations is almost always used as a model. Catch-up, however, does not mean cloning. What actually is achieved invariably diverges in certain ways from practice in the countries serving as the model.

In part this divergence reflects the fact that exact copying is almost impossible, and attempts to replicate at best get viably close. In part it reflects modifications required to tailor practice to local circumstances. The organizational, managerial and institutional aspects of productive practices are often the most difficult to replicate, and the most in need of adaptation to indigenous conditions, norms and values. So, each developing country does things in a different way, as a result of an indigenous process of learning.

The development process involves innovation in a sense of Schumpeter, as a break from traditional ways of doing things. In the process of catch-up the practices being brought in are certainly not new to the world, but they are new to the country, and bringing them in involves considerable risk, and requires a lot of trial and error in learning to be effective.

The learning of new capabilities by firms is of central importance in almost all economic sectors. In catching up many different kinds of capabilities need to be acquired. These capabilities involve a lot more than what engineers generally mean when they talk about technology. While important aspects of these activities are indeed structured or embodied in machinery or other physical artefacts they also involve modes of organizing coordinating and managing activities. These latter capabilities are often much more difficult to develop than the required engineering know-how. Thus various capabilities are needed for catch-up: capabilities to access complementary assets, absorptive capabilities, and innovation capabilities. All these capabilities are required in order to adopt, adapt and modify technologies developed elsewhere, introduce modifications and incremental innovations and eventually generate totally new products and processes.

But firms do not act alone. They are linked, upstream, to their customers, and downstream to their suppliers. More generally, they must be understood to be operating in the context of innovation systems that include other kinds of economic actors that are involved in supporting and orienting economic activity and innovation: primary and secondary education, universities, the public research system, and government programmes (Nelson, 2006). The structures of the financial system and of labour markets are also pivotal.

In the present era, the education system is of vital importance. Over the last century all the countries that have been successful in catching up have had a system of primary and secondary education that endowed a large fraction of the young population with the basic skills needed to operate in a modern economy, and also provided high-level training for a sufficient group of scientists and engineers to enable foreign technologies to be absorbed. The fact that today so much of technology is science based means that a country's system of advanced training in science, technology and the other bodies of knowledge needed to master modern ways of doing things is quite important. And research at universities and public laboratories has increasingly played a central role. Public sector research has long been an important element of catch-up in certain fields. This is certainly so in agriculture and medicine, where developing countries often could not simply copy technology and practice in countries at the frontier, but needed to develop technologies suited to their own conditions because soil, climate conditions and the prevalent diseases tend to be different.

In addition, active government policies have supported the catch-up process, involving various forms of protection and direct and indirect subsidy (as the cases of Japan, and of Korea and Taiwan illustrate). In many countries, however, these policies engendered not successful catch-up but a protected, inefficient home industry.

1.3 SECTORAL SYSTEMS AND CATCH-UP

This book is based on the belief that the concept of a sectoral innovation system is a useful one for illuminating the catch-up process in different economic sectors (see Malerba, 2002, 2004). While analyses of sectoral innovation systems and national innovation systems (see Freeman, 1987; Nelson, 1993; Lundvall, 1993) share a perspective that economic change is evolutionary, and that multiple actors are involved, the national innovation system concept is more aggregative and is particularly oriented to broad national characteristics. In contrast, the sectoral innovation system concept, while recognizing broad factors that influence development across a wide range of industries, is particularly concerned with highlighting characteristics of the environment within which development proceeds that are sectoral specific. The relevant sectoral system may involve some aspects that are national, but also others that are regional, and still others that are transnational. That is the perspective taken in this book.

Both the national and the sectoral innovation systems concept is associated with an evolutionary theory of economic change. Evolutionary theory places a key emphasis on dynamics, innovation processes and economic transformation (Nelson and Winter, 1982). Learning and capabilities are key elements in the change of the economic system. Boundedly rational agents act, learn and search in uncertain and changing environments. Agents know how to do different things in different ways. Thus learning, capabilities and behaviour entail agents' heterogeneity in experience and organization. Their different capabilities affect their persistent differential performance. A central place in the evolutionary approach is occupied by the processes of variety creation (in technologies, products, firms and organizations), replication including imitation (that engenders both continuity and a collective element to the process of economic development), and selection (that reduces variety in the economic system and discourages the inefficient or ineffective utilization of resources) (Nelson, 1995; Dosi, 1997; Metcalfe, 1998). For evolutionary theory the environment and conditions – such as the sectoral context – in which agents operate and which affect agents' cognition and behaviour may drastically differ.

Drawing from this perspective, a *sectoral system* framework focuses on the nature, structure, organization and dynamics of innovation and production in sectors. One can identify the following elements: (a) actors; (b) knowledge base; (c) institutions.

1.3.1 Actors

Firms

Much of the writing on industrial development as an evolutionary process is focused on business firms and the determinants of the evolution of their capabilities. Kim (1997) has identified different stages of capability development, from duplicative imitation to creative imitation to innovation.

Amsden and Chu (2003) have examined the combination of production engineering and design by large-scale enterprises in electronics in Taiwan. Lee (2005) has discussed the passage from the creation of absorptive capabilities to the development of complementary assets (complementary to those of firms in advanced countries). Lee and Lim (2001) have focused on different trajectories of catching up, from path-following to stage-skipping, to path-creating. Mathews (2002) and Lee (2005) have discussed different steps that firms have followed in the process, from OEM to ODM to OBM for Taiwan, and from OEM to OBM for Korea. The process sometimes goes from learning from FDI as an initial channel, to licensing, to indigenous R&D (for example, Amsden and Chu, 2003 for electronics). This last process, as Lee (2005) has pointed out, has to be supported in various ways: production and R&D consortia and joint ventures, scouting and foreign alliances and support from government research institutes. In this book we claim that firms' specific learning processes, competences and organizations, as well as beliefs, expectations and goals, are highly affected by the specific sectoral system in which they are embedded. In addition to firms active in a sector, other actors are relevant for innovation and production, but their importance, role and effects may greatly differ across sectors. They are:

Upstream suppliers of components and systems Suppliers may have different types of relationships with the innovating, producing or selling firms. In a dynamic and innovative setting, suppliers greatly affect and continuously redefine the boundaries of a sectoral system.

Users, customers and consumers (both national and international) In a sectoral system view, demand is not seen as an aggregate set of similar buyers or of atomistic undifferentiated customers, but as composed of heterogeneous agents who interact in various ways with producers. Demand may be largely local or national, or international. Transactions may involve close interaction between providers and customers, or may proceed through impersonal market arrangements. The principal customers may be firms or households. Particularly if they are firms, they may be highly sophisticated and demanding of quality, or they may be less so.

Universities and public laboratories In several sectors, universities play a key role in basic research, applied research, and human capital formation and this has proven crucial for economic development (Mazzoleni and Nelson, 2006). In addition, in some sectors (such as biotechnology and software), universities are also a source of start-ups and even innovation.

Financial organizations Finance plays a major role in supporting innovation, technology diffusion and production and does that with a variety of different organizations – from banks, to the stock market, to internal finance. In some sectoral systems, such as software or biotechnology-pharmaceuticals, new actors such as venture capital companies have emerged over time, but these financial organizations have played a different role according to the stage of the industry life-cycle.

Government Government and public policies play a major role in sectoral systems. In catch-up, they have often targeted specific sectors using a variety of tools and instruments. Think for example of semiconductors and computer hardware in Japan (Odagiri and Goto, 1993), Korea (Kim, 1997; Lee and Lim, 2001) and Taiwan (Mathews, 2002; Amsden and Chu, 2003; Hobday, 1995) and aircraft in Brazil (Dahlman and Frischtak, 1993; Viotti, 2002).

Networks of agents

Within any sectoral system, firms and non-firm organizations are connected in various ways through market and non-market relationships. The evolutionary approach and the innovation systems literature have paid a lot of attention to the wide range of formal and informal cooperation and interaction among firms. According to this perspective, in uncertain and changing environments networks emerge not because agents are similar, but because they are different. Thus, networks integrate complementarities in knowledge, capabilities and specialization (see Lundvall, 1993; Edquist, 1997). Relationships between firms and non-firm organizations (such as universities and public research centres) have been a source of innovation and change in several sectoral systems, such as pharmaceuticals and biotechnology, information technology, and telecommunications. The types and structures of relationships and networks differ greatly from sectoral system to sectoral system, as a consequence of the features of the knowledge base, the relevant learning processes, the basic technologies, the characteristics of demand, the key links, and the dynamic complementarities.

In the catching-up process, domestic firms benefit from being part of various types of networks. In some cases, vertical networks with suppliers have provided new inputs and shared relevant information for production and innovation, leading to capability development. Suppliers can be a major source of knowledge and innovation, because they can be characterized by high innovativeness, specific technological knowledge, and dynamic capabilities (Von Hippel, 1988; Lundvall, 1993). In some industries close interaction with sophisticated and demanding users has been an important vehicle for firm learning.

Networks vary in their geographical and substantive scope. In some cases local networks have been important for the catching-up process. For example, industrial districts, as in the case of Taiwan, have played a role in the development of the Taiwanese electronic industry. At the regional and local level, the presence of local networks allows intense formal and informal interaction, knowledge sharing, and intense division of labour. Such networks may involve horizontal collaborative agreements regarding production or R&D among domestic firms or between domestic firms and foreign firms. In this way, complementary knowledge and capabilities may be shared. Participation in the global value chain is another way to catch up. Here the participation in the network involve specialization in specific stages of production (Gereffi et al., 2005; Ernst, 2002), and it is particularly relevant in the electronics industry. Often global value chains are coordinated by some key (multinational) firms. A final way to catch up through networks is subcontracting. In a dynamic view of capability formation, subcontracting is considered one of the earlier forms of learning and catching up (Lee, 2005).

1.3.2 The Knowledge Base

Different sectors are characterized by different knowledge bases. Knowledge plays a central role in innovation and affects the types of learning and capabilities of firms. Knowledge can be highly idiosyncratic at the firm level, and where it is it does not diffuse automatically and freely among firms. In other cases, knowledge may be relatively easy to transfer or acquire. The evolutionary literature has proposed that sectors and technologies differ greatly in terms of the knowledge base and learning processes related to innovation. Firms need several different kinds of knowledge in order to operate effectively. One knowledge domain involves the specific scientific and technological fields at the base of innovative activities in a sector (Dosi, 1988; Nelson and Rosenberg, 1993). Other kinds of required knowledge relate to the nature of applications, and user needs. The sources of technological knowledge and opportunities markedly differ among sectors. As Freeman (1982), Nelson and Winter (1982) and Rosenberg (1982), among others, have shown, in some sectors research carried out in universities or public laboratories is a major source of new technological opportunities. In other sectors, while the knowledge contained in public science may play an essential background role, R&D carried out by firms in the industry directed to the design of new products and production processes is the driver of technological opportunities. In yet other sectors new types of equipment and instrumentation created by firms outside the industry may facilitate innovation by firms in the industry. In a dynamic way, the focus on knowledge and technological domain places at the centre of the analysis the issue of sectoral boundaries, which are usually not fixed, but change over time.

1.3.3 Institutions

Agents' cognition, actions and interactions are shaped by institutions, which include laws, standards, norms, common routines and habits, established practices, and so on. And institutions may range from those that bind or impose enforcements on agents to those that are created by the interaction among agents (such as standardized contracts); from more binding to less binding; from formal to informal (such as patent laws or specific regulations vs. traditions and conventions). While some institutions are national (such as the patent system), others are specific to sectors (such as sectoral labour markets or financial institutions). National institutions can also have different effects on different sectors. This is so for the patent system and IPR more generally. Often the characteristics of national institutions favour sectors that fit better the specificities of the national institutions. In certain cases particular sectoral systems become predominant in a country because the existing institutions of that country provide an environment more suitable for certain types of sectors than others. However, sometimes the direction of causality goes the opposite way, from the sectoral to the national level. In fact, it may occur that the institutions of a sector, which are extremely important for a country in terms of employment, competitiveness, or strategic relevance, end up emerging as national, thus becoming relevant for other sectors. But in the process of becoming national, they may change some of their original distinctive features.

One final general remark: catch-up is inherently a dynamic process. Because the various actors, knowledge and institutions are more or less closely connected, it follows that their change over time often results in sector-specific co-evolutionary processes, as Nelson (1994) and Metcalfe (1998) have discussed in a broad way. During the evolution of a sectoral system, change may occur in the technological and learning regimes and in the patterns of innovations. Often an industrial structure characterized by new firms and high turbulence may over time become oligopolistic with a more cumulative rate of technological change. Moreover, the knowledge base of innovative activities may change in different ways, such as the evolution towards a dominant design or as a consequence of a drastic change. In the first case, a growth of industrial concentration and the rise of large dominant firms may take place (Utterback, 1994). In the second case, new types of competencies may be required for innovation, with major industrial turbulence, entry of new firms and turnover in industrial leadership (Tushman and Anderson, 1986; Henderson and Clark, 1990). Finally, changes in demand, users and applications represent another major modification in the context in which firms operate and may favour the entry of new firms rather than the success of established ones (Christensen and Rosenbloom, 1995).

1.4 THE SECTORS EXAMINED IN THIS BOOK

This book examines five sectors: pharmaceuticals, semiconductors, telecommunications, agro-food and software. Here we briefly introduce the main features of the sectors (for a deeper discussion of some of these sectors, and of their evolution in the United States and Europe, see Mowery and Nelson, 1999 and Malerba, 2004).

1.4.1 Pharmaceuticals

In the early stages (1850–1945), the industry was related to chemicals. However, little formal R&D was carried out by pharmaceutical firms. The following period (1945 to early 1980s) was characterized by the introduction of large-scale deliberate screening of natural and chemically derived compounds to try to discover substances that might make useful pharmaceuticals. This required formal R&D. The advent of molecular biology in the 1980s led to a new learning regime based on molecular genetics and rDNA technology. In general, pharmaceutical products fall under one of three categories: drugs, vaccines and diagnostics. The commoditization of diagnostics is a recent phenomenon of the post-biotechnology period, as earlier all testing for detection of medical conditions was performed by trained personnel in clinical testing laboratories. The manufacturing of modern drugs and vaccines involves three main steps: the production or the acquisition of the 'active pharmaceutical ingredients'; the combination and process of active pharmaceutical ingredients into the 'bulk drug'; and the 'formulation' of the bulk drug in the form of a tablet, capsule, syrup, injection, plaster, and so on. The manufacturing capabilities associated with the three steps decrease in terms of technological complexity. Therefore, to catch up, developing country firms would start by developing manufacturing capabilities in 'formulations', acquiring the inputs from national and international markets. The next step would be to develop manufacturing capabilities in 'bulk drugs', buying the active pharmaceutical ingredients from the market, and the last step would be to establish 'active pharmaceutical ingredients' production units. In the pharmaceutical sectoral system, a wide variety of science and engineering fields play important roles in renewing the search space. The different industrial actors – large firms, small firms and new biotech firms – who generally do different things are connected through networks. In this sector, a very rich set of non-firm organizations and institutions greatly affect innovation, ranging from universities to public and private research organizations, the financial system and venture capital, the legal system and IPR. Demand channelled through agencies, physicians and the health system, and institutions such as regulation play a significant role in the diffusion of new drugs. Nowadays no individual firm can hope to gain control of more than a subset of the search space. The innovativeness and competitiveness of even the largest pharmaceutical firms depend on strong scientific capabilities and on the ability to interact, on one side, with science and scientific institutions (in order to explore such a complex space) and, on the other, with specialized innovative firms (in order to develop new products).

1.4.2 Telecommunications

In telecommunications, the knowledge base has been quite diversified because the sectoral system encompasses fixed communications, mobile phones, the Internet and other services. All these product groups present different features, but they are related in various ways technologically. In most developing countries, in recent years, mobile communications have overshadowed fixed line technology. This broad sectoral system has recently been affected by processes of convergence between information and communication technologies and between ICT and broadcasting-audio-visual technologies. Until the advent of the Internet, the telecom service industry did not experience major technological and market discontinuities. With the Internet and its open network architecture, modular components and distributed intelligence, both the knowledge base and the types of actors and competences have changed significantly. The process of convergence has generated the entry of several new actors coming from various previously separated industries, each one emphasizing different sets of competencies. Specialized competencies and specific knowledge have increasingly become a key asset for firms' survival and growth. Even more important in the new telecom environment is the combination of existing and new competencies – software programming, network management, content provision – which traditionally belonged to different companies. Networks among a variety of actors (not only firms, but also standard-setting organizations and research organizations) are relevant. Demand plays a key role in innovation, not just in terms of user–producer interaction, but also in terms of emerging service characteristics. Regulation, liberalization/privatization and standards have played a key role in the organization and performance of the sector, in the behaviour of incumbents and in the transformation of the structure of the industry. Given the complexity of its technology and the consequent huge investments required, the equipment part of the industry has in the past been dominated by a handful of MNCs based in the developed world. But the arrival of mobile technology has allowed enterprises from the developing world to enter this otherwise oligopolistic industry based in the North. The distribution segment, on the contrary, traditionally was nationally owned, very often by a public telephone and telegraph (PTT) provider. But with the liberalization and deregulation that has taken place in most countries, the distribution of telecom services has now been privatized and very often thrown open to private sector competition. The natural monopoly status enjoyed by the PTTs has been eroded. In most developing countries one could find only one part of the industry, namely the distribution segment, while the manufacturing segment is largely based in the developed world with most countries relying on imports of this equipment.

1.4.3 Computer Software and Services

The computer software industry is a global sector with multiple product and service niches. It is composed of software publishing, computer systems design and services, and data processing services. Also telephone call centres may be related to software. The software sectoral system has a quite differentiated knowledge base, with extended complementarities. Knowledge refers both to the control of the operations of the computer system, providing the platform for the different functionalities, and to the software employing these functionalities. The boundaries between operating systems and application software are becoming blurred, because of the dynamics of the inward and outward integration of software functions, outward (from system-level software to the user interface) and inward (from software designers to the definition of system resources). A very important distinction in the software industry is between mass-produced package software sold on impersonal markets, and software which is customized to particular uses and users, in terms of situated software, middleware software and fully custom software. These types of software require different types of knowledge and learning processes, and may have different intellectual property regimes. Mass-produced package software is characterized by the search for generic solutions, experience as a major input for innovation, and a key role of process innovation. Custom, situated and embedded software, on the other hand, have knowledge related to specific contexts, specialized purposes and specific applications, and often require close user–producer interactions. Recently, the changing knowledge base of software development and the blurring boundaries between operation systems and application software have created an evolving division of labour among generic 'platform' developers, specialized software vendors and users, and a further tension between horizontal integration and specialization. The historical key role of computer producers has largely been displaced by a division of labour between software and hardware 'platform' producers, governed by the needs of the other as well as by the aim to preserve market positions. For mass-produced software sold on the open market, IPR play a major role in strengthening appropriability, but have been greatly affected by the emerging open source movement. In addition, standards play a major role. Networks of users also play an increasingly important function, particularly in applications and in open source software. In sum, software has a highly differentiated knowledge base in which the context of application and user–producer interaction, global and local networks and high mobility of skilled human capital often play a key role.This has created several different and distinctive product groups.

1.4.4 Semiconductors

The semiconductor industry is characterized by a variety of actors doing different things, ranging from merchant semiconductor manufacturers, to silicon foundries, vertically integrated producers, and fabless[1] and design firms. The types of actors have been quite different from period to period and from country to country during the evolution of the industry. New entrants and specialized producers were quite relevant in the United States, with entrants particularly high either early on in the history of the industry or during phases of technological discontinuities. Large, vertically integrated producers were more common in Japan and Europe. In semiconductors, other main actors have played a major role. The military was one of the major factors responsible for the growth of the American industry, compared to that in Europe and Japan, because it supported the entry of new firms and provided competent firms with a large and innovative demand. During the 1970s in Japan, MITI was a major factor in allowing the Japanese industry, composed of large producers, to close the gap with American producers in some product ranges (such as memory devices). Although the processes of manufacturing semiconductor chips vary in sophistication – from simple transistors that replaced cathode ray tubes in the transfusion of pictures in televisions to sophisticated microprocessors that power supercomputers – the design and fabrication of chips remains high technology. Hence, catch-up attempts in fabrication have required lumpy investments in large physical plants, machinery and equipment, human capital, and its requisite matching demand. Scale economies have not fallen despite continued miniaturization and the decomposition of semiconductor manufacturing vertically into chip design, chip fabrication, assembly and test. Even in Taiwan scale requirements have driven up firm size. Recently, a change in the knowledge base of the industry which has allowed design modularity and has separated design from production, has lead to the entry of new types of actors, fabless firms, which are small firms focused on the design of components. As a consequence, countries that have advanced human capital and limited financial investment, may focus on only one part of the research and production process and enter the industry with small fabless firms.

1.4.5 Agro-food

The agro-food sector constitutes a crucial part of developing economies. Nearly half of the population of developing countries live in rural areas (the World Bank, 2008) and are mainly involved in agriculture. In this book, the case studies of four crops in different countries have been examined in order to shed light on the different dynamics of the sector growth and to explore the implications for development strategy.

A first crop examined is cassava in Nigeria. Cassava is Africa's second most important food staple, after maize, in terms of calories consumed, and it is widely acknowledged as a crop that holds great promise for addressing the challenges of food security and poverty reduction. Nigeria is currently the largest producer of cassava in the world. Most farmers in the main cassava belts of the south-eastern, south-western and central zones of Nigeria grow cassava. A second crop is vegetables in China. The emergence of a large and nationwide system for vegetable production, distribution and technological change, is a phenomenon that has been appearing in China along with rapid economic growth in the past twenty or so years. Earlier the sector was much smaller, weak in R&D and extension services, poor in variety provision, and developed primarily for farmer self-sufficiency. Demand factors, technological progress, and development of market institutions have all been major driving forces for the growth of the vegetable sector. A third crop is coffee in Costa Rica. Today, coffee is one of the most popular beverages worldwide, and one of the most traded commodities. Due to the limited areas suitable for coffee plantation which locate mainly in the South, and high income elasticity of coffee consumption, the coffee value chain is international. The coffee value chain embraces cultivation, milling, roasting, distribution and consumption. The two main cultivated species of the coffee plant are Arabica coffee and Robusta coffee. The former is considered higher quality than the latter. However, Robusta is less susceptible to disease and can be cultivated where Arabica will not thrive. Costa Rica cultivates Arabica. Also central America, eastern Africa and Arabia are Arabica cultivating areas. Western and central Africa, south-east Asia, and, to some extent, Brazil cultivate Robusta. The fourth crop is soybeans in Brazil. Soybeans are the primary ingredient in many processed foods: dairy product substitutes, soybean oil, tofu, veggie burgers, soynut butter and soy crisps, among others. The relevance of the soybean agro-industrial complex to the Brazilian economy rests on the fact that this sector is related to many processed foods and to a number of markets, the most important of which is the production and export of raw beans to the emerging international consumers in recent decades. Also important are the production of soybean oil and its by-products, and the production of animal feed. All these relate to agro-industrial meat chains.

1.5 THE MAIN QUESTIONS ADDRESSED

This book addresses several crucial questions related to catching up in different sectoral systems:

1. A first set of questions concerns the commonalities that are present in the process of catching up across different sectors.
   - Is it possible to identify some basic factors that are common to the five sectors examined?
   - Which is the most important factor across all sectors?
   - Does government policy play an active role in catching up?
2. A second set of questions deals with the specific sectoral differences.
   - Are there differences across sectors in the factors that affect the catching up of countries?
   - Is the industry structure conducive to catching up differences across sectors?
   - Are there other differences related to sectoral systems, such as demand, universities and institutions?
3. A third set of questions is related to country differences.
   - In a sector, are there differences across countries in terms of institutions and government policies?
   - And are these differences similar across different sectors?

- Do these national differences also affect the specialization of countries in specific sectors?

4. A final set of questions refer to the usefulness of the concept of sectoral innovation systems to organize the discussion about industry differences and catching up.
   - Is a sectoral system view able to identify the key variables that are responsible for innovation and catching up by a country in a sector?
   - Is a sectoral system view able to identify the main differences across sectors in those variables?
   - Does a sectoral system view point to the need to focus also on a meso dimension, such as sectors, as a relevant unit of analysis for catching up (in addition to a micro dimension, such as firms, and a macro dimension, such as countries)?

1.6 THE STRUCTURE OF THE BOOK

After this introductory chapter, five long chapters compose the main part of the book. Each chapter examines one sector and it is written by several authors. Then a concluding chapter discusses the main lessons emerging from the book.

We have deliberately chosen a methodology of having one single integrated 'sectoral' chapter written by authors from different countries rather than having different chapters, each examining the sector in a specific country. While this second route would have been easier in terms of coordination and delivery of individual papers, we are convinced that a multiple author 'sectoral' chapter provides a much better comparative and integrated view of the process of catching up in a sector in several countries. In this way, in fact, the main factors of development can be identified in a comparative perspective, and similarities and differences in the national experiences can be highlighted.

Undoubtedly, this effort has proved quite lengthy, research intensive and highly interactive because of the difficulty of having researchers from different countries and views working together in a coordinated way. Several meetings shaped the emergence of this book in order to discuss the various drafts, in New York, twice in Milan, in Maastricht and in Mexico City. But the meetings were indeed an exciting and enriching learning experience for all participants. And we are convinced that the effort was absolutely worthwhile and has proven very successful scientifically.

NOTE

1. Fabless firms are companies that design and sell devices and that outsource the fabrication to specialized manufacturers (foundries).

BIBLIOGRAPHY

Abramovitz, M. (1986), 'Catching-up, forging and falling behind', *The Journal of Economic History*, **46**(2), 385–406.

Amsden, A. and W. Chu (2003), *Beyond Late Development: Taiwan Late Development*, Cambridge: MIT Press.

Arora, A. and A. Gambardella (2005), *From Underdogs to Tiger: the Rise and Growth of the Software Industry in Brazil, China, India, Ireland and Israel*, Oxford: Oxford University Press.

Arthur, B. (1988), 'Competing technologies, increasing returns and lock-ins by historical events', *Economic Journal*, **99**(394), 116–31.

Athreye, S. (2005), 'The Indian software industry and its evolving service capability', *Industrial and Corporate Change*, **14**(3), 393–418.

Bell, M. and K. Pavitt (1993), 'Technological accumulation and industrial growth: contrasts between developed and developing countries', *Industrial and Corporate Change*, **2**, 157–201.

Bernardes, A. and E. Albuquerque (2003), 'Cross-over, thresholds and interactions between science and technology: lessons for less-developed countries', *Research Policy*, **32**(5), 865–85.

Breznitz, D. (2005), *Innovation and the State*, Cambridge: MIT.

Chandra, V. (2006), *Technology, Adaptation and Exports: How Some Developing Countries got it Right*, Washington, DC: The World Bank.

Christensen, C.M. and R.S. Rosenbloom (1995), 'Explaining the attacker's advantage: technological paradigms, organizational dynamics, and the value network', *Research Policy*, **24**(2), 233–57.

Cohen, W. and D. Levinthal (1989), 'Innovation and learning: the two faces of R&D', *Economic Journal*, **99**(397), 569–96.

Commander, S. (2005), *The Software Industry in Emerging Markets: Origins and Dynamics*, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

Cowan, R. (1990), 'Nuclear power reactors: a study of technological lock-in', *Journal of Economic History*, **50**(3), 541–66.

Dahlman, C. and C. Frischtak (1993), 'National systems supporting technical advance in industry: the Brazilian experience', in R. Nelson (ed.), *National Innovation Systems: A Comparative Analysis*, New York: Oxford University Press, pp. 414–50.

Dahmen, E. (1989), 'Development blocks in industrial economics', in B. Carlsson (ed.), *Industrial Dynamics: Technological, Organizational, and Structural Changes in Industries and Firms*, Boston, MA: Kluwer Academic Press.

Dosi, G. (1988), 'Sources, procedures and microeconomic effects of innovation', *Journal of Economic Literature*, **26**(3), 1120–71.

Dosi, G. (1997), 'Opportunities, incentives and the collective patterns of technological change', *The Economic Journal*, **107**(444), 1530–47.

Edquist, C. (1997), *Systems of Innovation: Technologies, Institutions and Organisations*, London: Frances Pinter.

Ernst, D. (2002), 'Global production networks and the changing geography of innovation systems: implications for developing countries', *Economics of Innovation and New Technology*, **11**(6), 497–523.

Fagerberg, J. and M. Godinho (2004), 'Innovation and catch-up', in J. Fagerberg, D. Mowery and R. Nelson (eds), *Handbook of Innovation*, Oxford: Oxford University Press, pp. 514–43.

Fagerberg, J. and M. Srholec (2006), 'The role of capabilities in development: why some countries develop (while others stay poor)', University of Oslo, working paper.

Fransmann, M. (2006), *Global Broadband Battles: Why the US and Europe Lag Behind While Asia Leads*, Stanford, CA: Stanford University Press.

Freeman, C. (1982), *The Economics of Industrial Innovation*, London: F. Pinter.

Freeman, C. (1987), *Technology Policy and Economic Performance: Lessons from Japan*, London: F. Pinter.

Gereffi, G., J. Humphrey and T. Sturgeon (2005), 'The governance of global value chains', *Review of International Political Economy*, **12**(1), 78–100.

Gerschenkron, A. (1962), *Economic Backwardness in Historical Perspective*, Cambridge, MA: Harvard University Press.

Gu, S., J. Adeoti, A. Castro, J. Orozco and B. Sinh (2007), 'The agro-food sector system', Draft, Catch-up Project.

Hayami, Y. and V. Ruttan (1985), *Agricultural Development: an International Perspective*, Baltimore, MD: Johns Hopkins University Press.

Henderson, R.M. and K.B. Clark (1990), 'Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms', *Administrative Science Quarterly*, **3**, 9–30.

Hobday, M. (1995), *Innovation in East Asia: the Challenge to Japan*, Aldershot, UK and Brookfield, VT, USA: Edward Elgar.

Hyun, Y., Y. Wang and M. Laplane (2007), 'The automobile industry in Brazil, China and Korea', draft, Catch-up Project.

Johnson, C. (1982), *MITI and the Japanese Miracle*, Stanford, CA: Stanford University Press.

Katz, J. (2005), 'Market-oriented structural reforms and domestic technological capabilities: lessons from the Latin American experience', working paper.

Kim, L. (1997), *Imitation to Innovation: the Dynamics of Korea's Technological Learning*, Boston, MA: Harvard Business School Press.

Kim, L. (1999), *Learning and Innovation in Economics Development*, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

Kim, L. and R. Nelson (2000), *Technology, Learning and Innovation: Experiences of Newly Industrialized Economies*, New York: Cambridge University Press.

Lall, S. (2001), *Competitiveness Technology and Skills*, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

Lee, K. (2005), 'Making a technological catch-up: barriers and opportunities', *Asian Journal of Technology Innovation*, **13**(2), 97–131.

Lee, K. and C. Lim (2001), 'Technological regimes, catching-up and leapfrogging: the findings from Korean industries', *Research Policy*, **30**(3), 459–83.

Lee, K., S. Mani and Q. Mu (2007), 'Explaining variations in the telecommunication equipment industry in Brazil, China, India and Korea', draft, Catch-up Project.

Lundvall, B.-Å. (1993), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Frances Pinter.
Lundvall, B.-Å. and B. Johnson (1994), 'The learning economy', *Journal of Industry Studies*, **1**(2), 23–42.
Malerba, F. (2002), 'Sectoral systems of innovation and production', *Research Policy*, **31**(2), 247–64.
Malerba, F. (2004), *Sectoral Systems of Innovation: Concepts, Issues and Analyses of Six Major Sectors in Europe*, Cambridge: Cambridge University Press.
Malerba, F. and S. Mani (2009), *Sectoral Systems of Innovation and Production in Developing Countries*, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.
Malerba, F. and L. Orsenigo (2000), 'Knowledge, innovative activities and industry evolution', *Industrial and Corporate Change*, **9**(2), 289–314.
Mani, S. (2004), 'Coping with globalization: an analysis of innovation capability in Brazilian telecommunication equipment industry', UNU-Intech WP 2004–3.
Mani, S. (2007), *Innovation Capability in Developing Countries: A Study of the Telecommunication Industry*, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.
Mani, S. and A. Bartzokas (2002), 'Institutional support for investments in new technologies: the role of venture capital institutions in developing countries', Intech Discussion papers no. 2002–4.
Mathews, J.A. (2002), 'Competitive advantage of the late comer firms: a resources based account of industrial catch up strategies', *Asia Pacific Journal of Management*, **19**(4), 467–88.
Mazzoleni, R. and R. Nelson (2006), 'The roles of research at universities and public labs in economic catch-up', LEM Working Paper Series.
Metcalfe, S. (1998), *Evolutionary Economics and Creative Destruction*, London: Routledge.
Morrison, A., C. Pietrobelli and R. Rabellotti (2006), 'Global value chains and technological capabilities: a framework to study industrial innovation in developing countries', Working paper.
Mowery, D. and R. Nelson (1999), *The Sources of Industrial Leadership*, Cambridge: Cambridge University Press.
Mu, Q. and K. Lee (2005), 'Knowledge diffusion, market segmentation and technological catch up: the case of telecommunication in China', *Research Policy*, **34**(6), 759–83.
Mytelka, L.K. (2000), 'Local system of innovation in a globalized world economy', *Industry and Innovation*, **7**(1), 15–32.
Nelson, R. (1993), *National Innovation Systems: A Comparative Study*, Oxford: Oxford University Press.
Nelson, R. (1994), 'The co-evolution of technology, industrial structure and supporting institutions', *Industrial and Corporate Change*, **3**(1), 47–64.
Nelson, R. (1995), 'Recent evolutionary theorizing about economic change', *Journal of Economic Literature*, **33**(1), 48–90.
Nelson, R. (2006), *Economic Development from the Perspective of Evolutionary Economics*, New York: Columbia University.
Nelson, R. and N. Rosenberg (1993), 'Technical innovation and national systems', in R. Nelson (ed.), *National Innovation Systems: A Comparative Analysis*, New York: Oxford University Press, pp. 3–21.

Nelson, R. and S. Winter (1982), *An Evolutionary Theory of Economic Change*, Cambridge: The Belknap Press of Harvard University Press.
Nelson, R., R. Mazzoleni, J. Cantwell, C. Juma, N. von Tunzelmann, S. Metcalfe, C. Henry, B.A. Lundvall, A. Goto and H. Odagiri (2005), *A Program of Study of the Process Involved in Technological and Economic Catch-up*, mimeo, Columbia Earth Institute.
Niosi, J. (2006), 'Success factors in Canadian academic spin-offs', *The Journal of Technology Transfer*, **31**(4), 451–7.
Niosi, J., S. Athreye, G. Britto and T. Tschang (2007), 'The global computer software sector', draft, Catch-up Project.
Odagiri, H. and A. Goto (1993), 'The Japanese system of innovation: past, present and future', in R. Nelson (ed.), *National Innovation Systems: A Comparative Analysis*, Oxford: Oxford University Press, pp. 76–114.
Ramani, S., M. Derengowski Fonseca and R. Mu (2007), 'The pharmaceutical sector', draft, Catch-up Project.
Rasiah, R., X. Kong and Y. Lin (2007), 'Semiconductors: explaining variations in catch-up strategies in Malyasia, China and Taiwan', draft, Catch-up Project.
Rosenberg, N. (1982), *Inside the Black Box*, Cambridge: Cambridge University Press.
Tushman, M.L. and P. Anderson (1986), 'Technological discontinuities and organizational environments', *Administrative Science Quarterly,* **31**(3), 439–65.
Utterback, J.M. (1994), *Mastering the Dynamics of Innovation: How Companies can Seize Opportunities in the Face of Technological Change*, Boston, MA: Harvard Business School.
Viotti, E. (2002), 'National learning systems: a new approach on technological change in late industrializing economies and evidences from the cases of Brazil and South Korea', *Technological Forecasting & Social Change*, **69**(7), 653–80.
Von Hippel, E. (1988), *The Sources of Innovation*, New York and Oxford: Oxford University Press.
Wade, R. (1990), 'Industrial policy in East Asia: does it lead or follow the market?', in G. Gereffi and D.L. Wyman (eds), *Manufacturing Miracles: Path of Industrialization in Latin America and East Asia*, Princeton, NJ: Princeton University Press, pp. 231–66.
World Bank (2008), *World Development Report 2008: Agriculture for Development*, Washington DC: The World Bank.