1 Introduction

The past three decades have witnessed rapid economic growth and a fascinating transformation of China's economy and industry, from an economy dominated by agriculture to one that is referred to as a 'world manufacturing plant', from a small exporter of resource- and unskilled-labour–intensive products to a major producer of manufactured exports. The total industrial output of China increased from US\$91 million in 1980 to US\$3,728 million in 2013, and the share of industrial products in total exports has increased from 50 per cent in 1980 to more than 95 per cent in 2012 (NBS, 2013).

Increasing industrial competitiveness as revealed through surging exports and upgraded export composition has also astonished the rest of world. China's total exports and imports increased from US\$38 billion in 1980 to US\$4,265 billion in 2012. China's share in the world markets for exports of goods rose from 0.9 per cent in 1980 to 11 per cent in 2012. More significant is the export of manufactured products from China, which increased from US\$9 billion in 1980 to US\$1,948 billion in 2012, 38 per cent of which constituted hightechnology products, accounting for 16.5 per cent of the world's total high-technology exports (UNCTAD, 2014). China is now the world's largest economy in terms of trade. The country has also maintained a fast growth rate despite the recent global economic crisis that severely affected the industrialised economies.

However, the country also faces significant criticisms of its growth model because of its heavy dependency on foreign technology transfer and imitation and its lack of creativity and indigenous capabilities in core technology. Moreover, with the amount of surplus unskilled labour in China falling, and the resource and environmental constraints for sustainable growth becoming increasingly significant, China is being forced towards a more skill-intensive and technology-intensive growth path as its own Lewis Turning Point approaches, that is, when the surplus labour in the subsistence sector is fully absorbed into the modern sector. China now faces significant challenges in moving from imitation to innovation. The success of this transformation will be of crucial importance for China to avoid the middle-income trap and sustain its long-term economic growth (Wu, 2013).

Therefore, given China's remarkable achievement in industrialisation and modernisation in the past three decades as well as the challenges of sustainable development and structural change ahead, it is pertinent to ask the following questions: What was China's path to innovation in the past, and whither the future? How has China managed to develop and upgrade its technological capabilities at such a remarkable speed? In the twenty-first century, how can China significantly enhance its indigenous innovation capability and accomplish the transition from imitation to innovation, thereby becoming an innovative nation? As one of the major economies in the world, how can China develop a path of compressed development and leapfrog the conventional latecomer path of imitative industrialisation, progressing up the value chain, taking a lead in the low-carbon industrial revolution and reemerge as the world's leading innovation power as documented for an earlier era in Joseph Needham's (1954) seminal work? Is there a China model of innovation? What are the lessons that other countries can learn from China's experience? These are all important questions of great interest not only to academic researchers but also to policy makers and practitioners.

As the world's second largest economy and one that is still firmly on a path of stable and promising economic growth, any fundamental changes in China will have significant impact on global business and global economies. Moreover, China has increasingly been seen as an exemplary model for other emerging economies. Its successes and challenges will thus be closely watched by policy makers in both developed and emerging economies. Therefore, findings from this book will have significant policy and practical implications for both developed and other developing countries.

Innovation and its sources

Innovation is a process of creative destruction, taking place as a 'process of industrial mutation that incessantly revolutionises the economic structure from within, incessantly destroying the old one, incessantly creating a new one" (Schumpeter, 1942: 83). It is widely recognised as a major driver of long-term growth and a key element of industrialisation and catch-up in developing countries (Romer, 1990). In the present context, innovation concerns not only novel innovations but also innovation via diffusion of existing ideas and techniques. It includes not only technological innovations but also non-technological innovations, such as new management practices and new institutional structures. In other words, innovation refers to the introduction or adoption of new products, new production processes, new ways of organisation and management, new methods of marketing and new business models. A complete innovation chain includes both the creation and commercialisation of new knowledge.

Innovation can occur as a result of a concerted focus by a range of different agents, by chance or as a result of changes in industry structure, in market structure; in local and global demographics; in human perception, mood and meaning; in the amount of already available scientific knowledge, and so on (Drucker, 1985). At the micro level, the sources of innovation may come from internal focus efforts, for example, R&D activities or other organised innovation efforts, or externally from the acquisition of useful technology or knowledge created by other organisations or by users of the technology, that is, the so-called end-user innovation identified by von Hippel (1988). Currently, with the innovation paradigm shifting from closed to open, firms may also open up their innovation process and create new products and processes by tapping into external resources and collaborating with other partners (Chesbrough, 2003). At the macro level, innovations may be created by focused efforts or by chance from a range of different agents in the country, such as firms, universities and research institutions. They may also emerge as a result of acquisition of innovations created in foreign countries through several channels.

Innovation can be diffused between firms and across regions and countries through various transmission mechanisms. These include (1) licensing; (2) movement of goods through international trade, especially imports; (3) movement of capital through inward and outward foreign direct investment (FDI and OFDI); (4) movement of people through migration, travel, and foreign education of students and workers; (5) international research collaboration; (6) diffusion through media and the Internet of disembodied knowledge; and (7) integration into global value chains to benefit from the foreign technology transferred within the supply chain. Some knowledge is transferred intentionally from the knowledge owner to the recipient – and this may spur

a learning process – but a large proportion of knowledge spillovers take place as unintended knowledge leakage. In recent years, the mode of innovation is becoming more and more open and good use is made of external resources. International knowledge diffusion can therefore benefit firms' innovation at every stage of the innovation process. The growing technological diversification of companies makes successful integration of new external knowledge into the innovation process increasingly important. Such successful integration further fosters innovation performance. The factors that explain the accelerating trend of utilising external sources of knowledge include, among others, technological convergence, declining transaction costs of acquiring external R&D inputs and shortening product cycle times (Narula, 2003).

The development strategies for industrialisation and catch-up in latecomer developing countries, the relative role of international technology transfer and indigenous innovation and the role of industry policy in the process have been the most important but also controversial issues in development studies and science and technology studies. One of the controversies is whether the sources of technological change are indigenous or rather based on foreign innovation efforts or a combination of the two, and which combination of different foreign sources of innovation with different degrees of emphasis. On the one hand, innovation is costly, risky and path dependent. Hence, it is more efficient for developing countries simply to acquire foreign technology created in developed countries. In principle, if innovations are easy to diffuse and adopt, a technologically backwards country can catch up rapidly, even leapfrog through the acquisition and more rapid deployment of the most advanced technologies (Soete, 1985; Grossman and Helpman, 1991, 1994; Romer, 1994; Eaton and Kortum, 1995).

On the other hand, there is the view that technology diffusion and adoption are neither costless nor unconditional. They rely on substantial and well-directed technological efforts (Lall, 2001) and on absorptive capacity (Cohen and Levinthal, 1989). An additional related difficulty in the debate on indigenous versus foreign technology upgrading is that technical change is often biased in a particular direction so that foreign technologies developed in industrialised countries may not be appropriate to the economic and social conditions of developing countries (Atkinson and Stiglitz, 1969; Basu and Weil, 1998; Acemoglu, 2002; Fu and Gong, 2010). In addition, we cannot simplistically assume that the private interests of multinationals coincide with the social interests of the host countries (Lall and Urata, 2003). The available empirical evidence on the effects of the sources of indigenous or foreign innovation is mixed. Studies largely fail to provide convincing evidence indicating significant positive technological transfer and spillover effects of FDI on local firms (Gorg and Strobl, 2001).

Accompanying this ongoing and inclusive debate on the role of technology transfer and indigenous innovation, the role of state and industry policy in the process of industrialisation and economic development is also subject to a wide, ongoing debate. While some argue that industry policy is crucial for the success of the newly industrialised economics (NIEs) such as Japan, South Korea and Signapore (Amsden, 2001; Chang, 2003; Pack and Saggi, 2006), there are also strong arguments for the role of the market and free competition in allocating resources efficiency and enhancing the productive efficiency of the enterprises in an economy based on the recent success of the East Asian Tigers such as Malaysia, Thailand and the Philippines (Kruger, 1974; Bhagwati, 1982; World Bank, 1996, 2005).

Some argue for a third way for structural change to occur, suggesting that sustained economic development is driven by changes in factor endowments and continuous technological innovation; therefore, industry policy should encourage the development of sectors that comply with a country's comparative advantage while the private sector and the market should be the major players in the process (Lin, 2011). Market forces and private entrepreneurship would be in the driving seat of this agenda, but governments would also perform a strategic and coordinating role in the productive sphere beyond simply ensuring property rights, contract enforcement, and macroeconomic stability (Rodrik, 2004). This debate on the role of the state and policy is relevant for our analysis of national innovation capabilities and performance because of the nature of innovation as a public product, the significant positive externalities that knowledge and ideas may generate and the presence of market failures resulting from the great uncertainty related to the innovation process.

The literature

China's experience with innovation and technological upgrading is also the subject of wide-ranging interests amongst a variety of stakeholders in economics and politics. The literature in this area can be broadly classified into several categories. The first category relates to studies of the impact of China's rising innovation and technological capabilities on the rest of the world, for example, MacDonald et al. (2008), Barlow (2013) and Someren and Someren-Wang (2013). These studies argue that the United States, the EU and China have reached a crossroads, and whether China will be a threat or an opportunity depends on the main players in government and public and private organisations rethinking their innovation policies and business development paths (Someren and Someren-Wang, 2013). They also contend that the 'rules for survival' in R&D and education are changing in favour of China, in terms of basic R&D parameters such as research expenditure, scientists trained, papers published and patents awarded (MacDonald et al., 2008).

The second category in the literature on China's innovation capabilities concerns one or several individual factors in the national innovation system or one type of innovation in China, for example, university-industry linkages, state-firm coordination, high-end talents, disruptive innovation in China and cost innovations (e.g., Zeng and Williamson, 2007; Feng, 2009; Simon and Cao, 2009; Tan, 2011). The third stream of literature relates to industry case studies, most of which focus on the high-technology industries, the information and communication technology (ICT) sector and green technologies (e.g., Lu, 2000; Jakobson, 2007; Wang, 2012; and Liu et al., 2012).

All these studies have provided useful insights about the development of innovation and technological capabilities in China. However, they are based on studies of a particular industry, a particular type of innovation, or one specific driver of innovation. What is China's national strategy and path to innovation? Comprehensive and systematic analysis of China's overall innovation strategy, driver and outcome is rare with very few exceptions (e.g., Varum et al., 2007; OECD, 2008). Varum et al. (2007) present a comprehensive description of the transformation of innovation policies and the reform of science and technology systems in China from 1978 to 2004. OECD (2008) provides a comprehensive and systematic review of China's national innovation system. Features and performances of each of the major players, that is, government, industry and universities, and the role of policy and governance are examined. Both of these studies set up their analysis under the national innovation system framework. They provide a valuable description of the relevant policies and the status and performance of the important agencies in China's national innovation system. However, how China achieved its current success and how china can achieve its new objective to transform itself into an innovation-driven economy is still underresearched. Our understanding is limited with regard to the evolution of China's path to innovation, in particular the evolution of strategies,

processes and drivers of innovation at different stages of development and their impact on China's innovation capabilities and technological upgrading.

The objective and structure of the book

The objective of this book is to provide a systematic, comprehensive and rigorous study of China's drive towards innovation in the past and for the future. It draws on my research of more than a decade to understand, analyse and evaluate this process. The research employs the rigorous analysis and empirical methodology of modern economics as well as in-depth case studies of representative industries and leading Chinese companies. Much of the evidence is based on either survey data or longitudinal data at firm-, industry-, regional- or country-level. But a systematic approach is adopted: economic and management theory, development and evolutionary theory, institutional analysis and political economy are used to explain the motivation, sources, obstacles, policy measures, firm responses and consequences of China's drive towards being an innovative nation, and the roles played by the state, the market, the private sector and the non-market, non-state institutions such as universities and public research institutions.

In addition to the analysis of China's experience in the past three decades, the book also investigates some of China's most recent efforts in innovation, for example, internationalisation of Chinese MNEs and outward direct investment for technology acquisition and upgrading, international innovation collaboration, reforms of incentive structure at multiple levels, and the development of green technologies. Moreover, the research places China in a global context, and an international comparative perspective is taken comparing China with other emerging economies such as India and more advanced countries such as the UK. The book also critically reviews China's experience, provides an in-depth discussion of the likely way forward, and what other countries can learn from China's experience.

In light of the economic and management theories on the sources of innovation, taking on board the innovation systems framework and the capabilities approach, the book is organised into three parts focusing on the drivers of innovation at different stages of development, in addition to the Introduction and Conclusions chapters. Part I examines the role of international knowledge transfer and technological takeoff in China at the early stage of the reforms. Part II analyses the development of indigenous innovation capability in the catch-up stage of industrial development in China. Part III focuses on China's current efforts to leapfrog the country into the role of global innovation leader and assesses the role of incentive structure, institutional arrangement and unconventional knowledge sourcing and co-creation measures in the process. Before embarking on these analyses, an overview of China's innovation efforts and performance in the past three decades since the reforms is presented in Chapter 2.

Part I on the role of international knowledge transfer and technological takeoff in China includes four chapters. Chapter 3 investigates the impact of foreign direct investment on the development of regional innovation capabilities using a panel data set of Chinese regions. It finds that FDI has a significant positive impact on the overall regional innovation capacity. FDI intensity is also positively associated with innovation efficiency in the host region. The strength of this positive effect depends, however, on the availability of the absorptive capacity and the presence of innovation-complementary assets in the host region. This increased regional innovation and technological capability has contributed further to regional economic growth in China's coastal regions but not in the inland regions. It concludes that the type and quality of FDI inflows and the strength of local absorptive capacity and complementary assets in the host regions are crucial for FDI to serve as a driver of knowledge-based development. Policy implications are discussed.

Chapter 4 examines the impact of processing trade-oriented FDI on the export competitiveness of indigenous firms using disaggregated firm-level production data and product-level trade data from China covering 2000 to 2007. The estimation results show that processing trade-FDI has generated significant positive information spillover effects on the export performance of indigenous firms. However, the effect of technology spillovers on the development of international competitiveness in indigenous firms is limited and in fact exerts a significant depressive effect on the propensity to export in these firms. Indigenous innovation, economies of scale and productivity are found to be the main drivers of export performance in indigenous firms in the high-technology industries.

Chapter 5 explores the role of indigenous and foreign innovation efforts in technological upgrading in developing countries, taking into account sectoral specificities in technical change. Using a Chinese firm-level panel data set covering 2001 to 2005, the chapter decomposes productivity growth into technical change and efficiency improvement and examines the impact of indigenous and foreign innovation efforts on these changes. Indigenous firms are found to be the leading force on the technological frontier in the low- and medium-technology industries, whereas foreign-invested firms enjoy a clear lead in the high-technology sector. Collective indigenous R&D activities at the industry level are found to be the major driver of technology upgrading of indigenous firms that pushes out the technology frontier. While foreign investment appears to contribute to static industry capabilities, R&D activities of foreign-invested firms have exerted a significant negative effect on the technical change of local firms over the sample period.

Part II on the development of indigenous innovation capability in the catch-up stage includes five chapters. Chapter 6 attempts to review the evolution of policies and practices of open innovation in China using historical archives and case study approaches, covering policies and practices at both the macro and micro levels. It finds that Chinese firms have in practice employed a variety of open innovation models since the reforms of science and technology systems in the mid-1980s. Policies introduced by the Chinese government with respect to inbound and outbound open innovation as well as policies encouraging open innovation modes and practices. With the increasing internationalisation of R&D and globalisation of production, open innovation is diffusing rapidly in China. Challenges to adoption of open innovation for latecomer firms and the implications for latecomer firms in building indigenous innovation capability are also discussed.

Chapter 7 examines how Chinese firms use open innovation as a response to the constraints and risks of innovation that they face. A national firm-level survey of 1,400 firms in the manufacturing sector is used as the basis of the analysis. It found that institutional-, financialand knowledge/skills-related risks and constraints are all significantly associated with firms' depth and breadth of openness in innovation. The responses, however, vary across firms of different ownership types. Foreign invested firms appear to be most responsive and take action to widen and deepen their openness in innovation. Privately owned firms have made significant responses to market/institution-related and finance/risk-related impediments but not to knowledge/skills-related ones. State-owned firms appear to be least responsive in the use of open innovation. Firm size and industry-specific effects also appear to have significant moderating effects on firms' responses to the various constraints. These findings are supported by an in-depth study of the Chinese semiconductor industry.

Chapter 8 attempts to investigate the role of universities in industrial innovation in emerging economies using a firm-level survey database from China. It also benchmarks the Chinese pattern against that of the UK. It finds that domestic universities have played a significant role in the promotion of the diffusion of frontier technology and the creation of new country- or firm-level innovation outcomes in China. In contrast to the traditional view that collaboration with universities will lead to greater novel innovation (an outcome that is supported by evidence from the UK), the contribution of domestic universities to the creation of groundbreaking innovations is limited in China. International innovation collaboration with foreign universities, especially those in the NIEs and the emerging South, appears to be fruitful in enhancing the creation of groundbreaking innovations in Chinese firms.

Chapter 9 provides an analysis of the relative significance of various methods of acquiring tacit knowledge within the Chinese optical fibre and cable industry. The chapter contributes to the definition, understanding and investigation of tacit knowledge using firm-level data in a developing country context, helping complete a gap in the existing broader literature on technological learning. The research suggests that in industries where tacit knowledge is a more important component of technological learning than codified knowledge, internal R&D activities and domestic peers are important knowledge sources. Additionally, universities are shown to be an important asset in creating learning organisations, and they provide effective knowledge sources of both tacit and codified knowledge. However, imports of equipment and licensing are a less effective learning channel in the acquisition of tacit foreign technology.

In recent years, China and India have achieved tremendous technological progress and development in the solar photovoltaic (PV) industry. Using case studies, Chapter 10 analyses and compares the technology progress processes in the solar PV industry in China and India, and it discusses the role national innovation systems played in sustaining technology acquisition, adaptation and development. It illustrates that both countries adopted a strategy of mixing and sequencing different technology transfer and indigenous innovation mechanisms. The experiences of both countries also suggest that a functional national environmental innovation system is important in sustaining and advancing technology acquisition, adaptation and development. This chapter provides an alternative pathway for developing countries to follow in catching up with developed countries in the emergent green industries and leapfrogging towards an internationally competitive green economy.

Part III on China's current efforts to leapfrog the country into a global innovation leader includes four chapters. Chapter 11 analyses the patterns of reverse learning and sequential capabilities development in Huawei and ZTE, China's two successful ICT multinational enterprises. The chapter analyses the internationalisation process of Huawei and ZTE, their learning activities in the host countries, channels for reverse knowledge transfer from one subsidiary located in developed countries to headquarters and other subsidiaries worldwide. Findings from this chapter reveal three processes of reverse learning and capabilities upgrading: learning from customers, collaborators and other subsidiaries of the company group. Findings from this case study have valuable implications for organisational learning in MNEs from developing countries.

Chapter 12 examines the role of international innovation collaboration in the process of radical innovation in China. Radical innovations represent major departures from existing practices and involve the disruptive creation of new insights. Accordingly, the launch of radical innovation requires an extension of both the depth and breadth of knowledge. This chapter investigates the patterns of international and domestic innovation collaboration in 819 Chinese firms from 2006 to 2008. It finds that collaborations with foreign partners have made a significant positive impact of the creation of novel innovation in Chinese firms. The type of foreign partners that Chinese firms may benefit by collaborating with covers a wide range, including foreign customers, suppliers, universities, private research institutions and firms in the same industry. Collaboration with foreign customers generates the largest benefits in the creation of novel innovation. Collaboration with foreign universities also proved to be fruitful for the generation of novel innovations that are new to the world, which is consistent with the findings of Chapter 8.

Chapter 13 benchmarks the patent activities of countries against the world frontier and explores the sources of the cross-country differences

in innovation (proxied by patenting). A patent production frontier is first estimated for a panel of 21 OECD countries from the 1990 to 2002 period using stochastic frontier analysis. Patenting performance for each country is decomposed into basic patenting capacity and patenting efficiency. The gap between Europe and the world leaders in terms of basic patenting capacity remains substantial with little sign of convergence over the sample period. In terms of patenting efficiency, Japan, Germany and Italy have improved their relative positions in recent years. Institutional factors are found to be significantly associated with the patenting efficiency of an economy. Then, China and other emerging economies are brought into this benchmarking exercise using crosscountry panel data covering 2005 to 2011. The gap in patenting performance between China and the world frontier results from China's relative underperformance mainly in the efficiency of innovation production.

Chapter 14 examines the policy choices for China's drive to transforming the country into an innovation-driven economy. Innovation capabilities, incentives and institutional frameworks are examined. The chapter argues that China should continue to increase its investment in R&D and in education, and that there should also be an attempt to strengthen the incentive system at the macro, meso and micro levels. This strengthening may include the following reforms: release the power of competition and guide resources towards innovative sectors; adopt appropriate human resource management policies, such as appraisal and remuneration systems; create effective policies for research funding management; and evaluate the efficiency of research to encourage the creativity of researchers, managers and employees. The chapter also discusses the space for industrial policy in the twentyfirst century.

Chapter 15 summarises the main findings of the book, discusses the implications for other countries and identifies issues for further research. Based on the comprehensive analysis of China's path to innovation that is presented in the book, a model of an open national innovation system (ONIS) is developed and the stage-specific mixing and sequencing characteristics of the model and implications for other developing countries are discussed. Instead of being the often presented 'state-led model of innovation' in China or a pure market-driven model of innovation, the ONIS model in China is a multi-driver model led by the state, the private sector and the MNEs, with each of them playing a leading role in different segments of the economy and the innovation system.