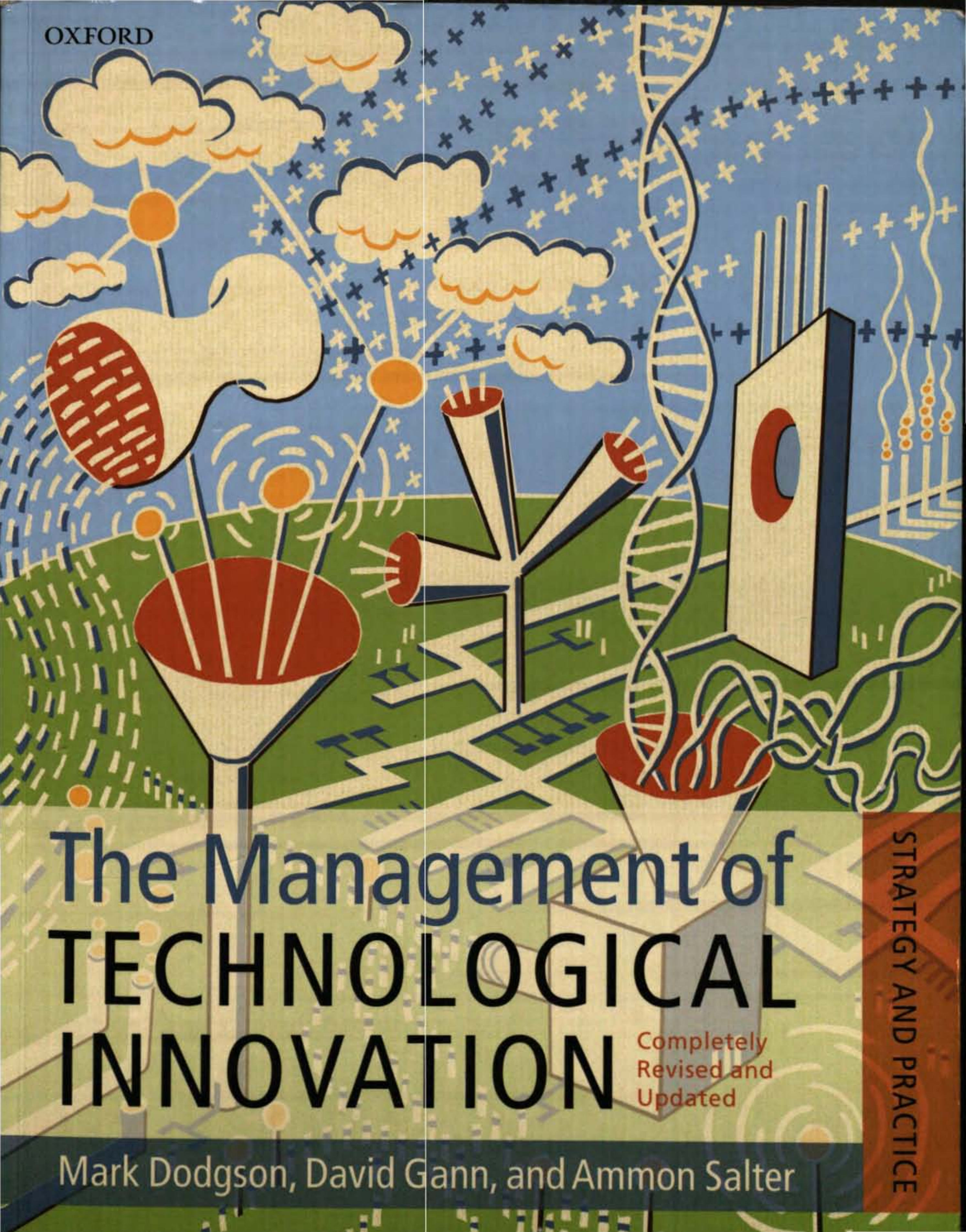
OXFORD



The Management of TECHNOLOGICAL INNOVATION

Completely Revised and Updated

STRATEGY AND PRACTICE

Mark Dodgson, David Gann, and Ammon Salter

The Management of Technological Innovation

Strategy and Practice

Completely Revised and Updated

Mark Dodgson
David Gann
Ammon Salter

OXFORD
UNIVERSITY PRESS

1 What is the Management of Technological Innovation and Why is it Important?

Introduction

Of all the challenges faced by managers today, the management of technological innovation (MTI) is one of the most demanding. Get it right and firms create value and profit, develop sustainable competitiveness, and become vibrant, fun places to work, attracting and retaining the most productive and creative staff. Get it wrong and firms can face serious, and perhaps terminal, problems through losing money, workers, and reputation. In the vast majority of business sectors, if firms do not innovate, their competitors will, and they will be put out of business in any case.

The overarching objectives of managers lie in improving efficiencies and enhancing sustainable competitiveness in their organizations. As we show in this book, technological innovation plays a major role in helping managers meet these objectives. Successful MTI occurs when all the wide range of innovative elements and activities of organizations are managed well and effectively combined within an innovation strategy. This allows firms to fulfil their overall purpose—be it profit generation, growth, better quality and range of delivery, greater market share, or increased employee remuneration, job security, or satisfaction. This book examines the ways in which MTI contributes to meeting the challenges and realizing the objectives of firms and organizations.

MTI encompasses all those elements of firms where developing and using technological innovation improves capacity to meet objectives. It includes the management of innovation strategy, innovation communities and networks, research and development (R & D), design and new product and service development, operations, and value delivery. While there are many incentives to innovate, there are considerable obstacles to success. MTI often involves managing in circumstances where there is a high degree of ambiguity, uncertainty, and risk. As technological innovation is for many firms the primary means of competing in the knowledge-intensive economies of the twenty-first century, MTI is a vital activity.

Box 1.1 Definitions of technology and innovation

Technology is a replicable artefact with practical application, and the knowledge that enables it to be developed and used. Technology is manifested in new products, processes, and systems, including the knowledge and capabilities needed to deliver functionality that is reproducible.

Innovation is much more than invention—the creation of a new idea and its reduction to practice—and it includes all the activities required in the *commercialization* of new technologies (Freeman and Soete 1997). Essentially, innovation is the successful commercial exploitation of new ideas. It includes the scientific, technological, organizational, financial, and business activities leading to the commercial introduction of a new (or improved) product or service.

Firms compete successfully when they offer new, better, and/or cheaper products and services, which their customers can use to advantage, and which their competitors cannot provide. Competitive advantage therefore derives from the ability to make and do things more cheaply and better, or to make and do new things. It has a relative dimension: advantage is found in the activities of firms compared to their competitors. It also has an absolute dimension: there must be a market for what the firm does. Technological innovation plays a central role in providing comparative and absolute advantages.

Although we might be very clear in our minds about what constitutes technological innovation—that is, a new computer, automated telling machine (ATM), or pharmaceutical—definitions of technology and innovation are actually very broad ranging (see Box 1.1). This highlights how technological innovation can occur in many, often unexpected, sectors, demonstrated in our case studies on innovation in condoms, food, cruise ships, and car insurance. Innovation also involves many more parts of a firm than the 'technology' areas. Decisions on strategy, organization, finance, marketing, and location of business are made alongside those related to research, design, and operations (see Box 1.2). The challenge for business is to make effective decisions in each of these different areas, often at the same time. These features point to the complexity of technological innovation, and hence to the challenge of managing it.

From these definitions we can see that technological innovation involves more than the successful application of new ideas to products and services; it often requires changes in the organization and strategies that support it. As we shall see from the following case studies and Chapter 2, technological innovation involves addressing a wide range of issues and activities that compound the challenges in managing it, add to its risk and uncertainty, and make it difficult to develop generic recipes for its success. It is the very difficulty of managing technological innovation that makes it such a source of competitive advantage. If every firm could do it successfully, it would not provide a source of relative competitive advantage. As Frederick Gardner Cottrell of the University of California and a founder of the US Research Corporation said in 1912: '[A] number of meritorious patents given to the public absolutely freely by their inventors have never come upon the market chiefly because "what is everyone's business is nobody's business"' (Cottrell 1912 quoted in Mowery et al. 2004: 59).

To add to the complexity, there are different types and dimensions of innovation. Innovation is at once an *outcome*, a new product, process, or service, and a *process* of managerial and organizational combinations and decisions. An innovation, by definition, is successful (although it may be limited or short lived; in Chapter 7 we discuss the ambiguity surrounding definitions of success and failure). Any innovation *process*, in contrast, can fail to support the successful exploitation of new ideas.

Innovation is found in products, processes, or services, but the boundaries between them can be blurred and one company's product may be another's process. Innovation can involve minor *incremental* adaptations and improvements in a product or small component of a system, or *radical* changes to the whole product or system. It may be new to the firm, industry, or nation, or new to the world. It can emerge from existing technologies or completely new ones. Most often it materializes from new combinations of existing technologies. Another factor affecting MTI lies in the innovation process itself, which, as we shall see in Chapter 3, is changing. All the various types and levels of innovation and innovation processes pose different challenges for managers.

MTI requires a broad appreciation of the business and industry context in which it occurs. Chapter 2 discusses the contextual and influential issues for MTI of technological change, the knowledge economy, business and innovation systems and networks, the changing nature of management, and globalization.

Subsequent chapters address a wide range of MTI issues.

In a business environment where innovation provides distinctive and sustainable competitive advantages, *innovation strategy* is the basis for the firm's overall strategy. Innovation strategy involves analysis of firms' business, market, and technological environments and consideration of what resources they have to draw upon. It involves making choices about innovation in uncertain and ambiguous circumstances, with diverse strategies for different levels of uncertainty. It entails building the innovative capabilities firms need, to meld skills and resources to analyze, select, and deliver innovation to enhance organizational performance. It requires consideration of how new initiatives in innovation fit with firms' existing portfolio and how innovation strategy complements overall corporate strategy. It is concerned with integrating all the areas of MTI into a coherent whole. Innovation strategy is discussed in Chapter 4.

Small and medium-sized enterprises (SME) face particular issues in their innovation strategies, especially in relation to the problems of managing growth, and these are discussed in Chapter 4.

Technological innovation rarely occurs through the activities of single firms. It is more commonly a result of inputs from a variety of organizations, working together as customers and suppliers, in various forms of *communities and networks*, and in formal *technological collaborations*. MTI therefore includes technological collaboration, alliances, and networks. This aspect of MTI is examined in Chapter 5.

Centrally important is the management of *research and development* (R & D), which provides an organized source of idea generation and improves the ability of firms to absorb useful information from outside. MTI includes issues ranging from techniques of technology forecasting and assessment to organizational questions, such as the extent of the centralization or decentralization of R & D, the degree to which R & D is internationalized, and the ways internal capabilities link with external sources of R & D—in universities, research institutes, and other companies. It includes balancing shorter-term, applied R & D and longer-term, more speculative basic research. It involves managing creative and productive researchers and research teams. Managing R & D is discussed in Chapter 6.

MTI entails the management of *product and service innovation*. This includes *efficiency* factors, encouraged, for example, through the use of various project management systems; and *effectiveness* factors, such as whether chosen new products and services complement and build upon firms' existing product bases, expertise, reputations, and overall innovation strategies. The management of *design* is an important component of new product and service development. Design entails selection of elegant and efficient choices to provide a solution. It encompasses choices made in relation to aesthetic appeal and delight, impact, function, and reliability. These elements of MTI are examined in Chapter 7.

The management of *operations and process innovation* includes the way operations and production complement existing activities, and provide options for new innovation activities. Its management is concerned with broad business and organizational issues. Some of the innovations in the management of existing operations, for example, in quality will be discussed. And innovation in new processes, such as new relationships with suppliers, will be described. Specific focus will be placed on the move from mass to 'lean' and 'agile' production and consumption and the combination of operation capacities with those of design and development, and the integration of supply chains. MTI and operations are discussed in Chapter 8.

The eventual aim of MTI is the *delivery of value*, and the process of commercialization—that is, obtaining returns from innovation investments—is a central element of MTI. Appropriating value from firms' investments in technological innovation involves consideration of intellectual property rights (IPR), licensing, the creation of technical standards, speed, and secrecy, and the ownership of 'complementary assets'. The so-called appropriability regime identifies the extent to which firms can ensure that they receive adequate returns from their investment. Commercialization may not be immediate, firms can valuably expand options for the future through the innovation process, and this has to be considered when evaluating its commercial returns. These issues are discussed in Chapter 9.

Box 1.2 Innovation in manufacturing and services

The boundary between services and manufacturing industry is increasingly blurred (Quinn 1992; Miles 2000; Dougherty 2004; Davies and Hobday 2005). Is a company that designs car engines a manufacturing firm or a service firm? Can IBM be considered a manufacturing firm when the focus of its strategy is to supply customer 'solutions' rather than products? Are software houses (sometimes known as software factories) using highly computerized writing tools, making products? Many important activities carried out by manufacturing firms—marketing, distribution, engineering, design, maintenance, accounting—would be described as services if they were supplied externally. Many services such as bank telling are now delivered electro-mechanically, and the value of manufactured products often lies in intangible attributes such as speedy delivery, convenience of use, brand identity, and reliability, which, if not embodied in products, would be thought of as services (Lester 1998). Many service companies describe their offerings as products. Furthermore, many physical products are packaged together with intangible services (Davies 2004). An example is Ericsson's and Nokia's packaging of services around their products. As service companies create R & D capabilities—to increase product differentiation, reduce costs of developing and delivering services, and protect proprietary technology—they are dealing with many issues analogous to those in manufacturing firms. Therefore, the majority of the issues discussed in respect to MTI apply equally to services and manufactured goods. Cases and examples will be provided of both manufacturing and service companies.

The ways in which technological innovations are developed and used continue to change and MTI responds by being a dynamic and evolving field of practice. New challenges are emerging around strategies for technology-based competition, the role of the government, the contribution of basic research, the evolving innovation process, and environmental concerns. These issues are discussed in Chapter 10 of the book.

The management of information technology (IT) and information systems (IS) is incorporated within these areas and is not included as a distinct area of MTI. Many strategic and organizational issues, such as the development of new IT products and software and the use of IT and IS in R & D and operations, are included in the definition of MTI and are therefore discussed here.

Why is MTI so important?

The question of why MTI is so important is examined from a corporate, national/industrial, theoretical, and individual perspective.

A CORPORATE PERSPECTIVE

MTI is important for firms' growth, profitability, and survival. History is littered with examples of companies that went out of business because they could not keep up with the demands of innovation. Each of the various areas of MTI is important, but some are critical for particular firms. The ability of pharmaceutical and electronics firms to compete, for example, depends upon their capacity to manage R & D. It is R & D that provides the opportunities to create distinctive new products and markets. Drug companies, such as GSK, Pfizer, and Merck, rely on research to create highly profitable drugs for treating ulcers or producing AIDS inhibitors. Companies such as Sony in consumer electronics, Samsung in DRAM semiconductors, BMW in cars, HSBC with its online financial services (First Direct), and Google with its search engines, depend on new products and services to provide the means by which they compete, and these innovations to a large extent define their companies. Operations prowess endows companies, such as Toyota, with the ability to produce better cars more cheaply than the competitors, and enables electronics companies, such as Acer in Taiwan, to produce efficiently for major electronics industry customers in the USA, Europe, and Japan. The success of supermarkets, such as Wal-Mart and Tesco, depends to a significant extent on their highly innovative operations.

When NEC decided it wanted to develop expertise in semiconductors, which it saw as a key strategic technology central to its competitiveness in a number of industries, it used over a hundred technological alliances to do so. Powerful technology companies, such as Boeing, are heavily reliant on their communities and networks. Boeing now works collaboratively in the production of aircraft, with partners responsible for the design and manufacture of major components, such as engines, fuselage, and rudders. Boeing can no longer design and manufacture aircraft by itself.

Companies often fail to obtain value from their technological innovations. Ampex failed to see the real market for its developments in video recorders. RCA, famously, did not make the business transition from vacuum tubes to transistors. The effectiveness and quality of the commercialization process determine the outcome of technological innovation. Sony's Betamax video system was technically better than Matsushita's competing VHS system, but lost out in the competition for the consumer market. The IBM personal computer was in many ways inferior to other competing products, but became hugely successful. The ability of Matsushita and IBM to commercialize their innovations more effectively than their opponents provided their competitive advantage.

Of all the aspects of MTI, innovation strategy is the most demanding. Very few companies have consistently been capable of developing and implementing innovation strategies. Adopting leading positions in technology can confer significant competitive advantage. SAP, the German applications software company, benefited significantly from foreseeing the importance of using Unix then Microsoft NT systems with its customers. Similarly, when market assessments are accurate and prescient—such as when Matsushita saw the market in home video recorders—innovation leaders can benefit significantly. At the same time, leaders can fail to capitalize on new ideas, allowing product innovation followers, such as Dell, to succeed. As Chapter 4 shows, firms in the same industry pursue a variety of different strategies in line with their resources, capabilities, and ambitions. When these strategies are well chosen, significant benefits accrue. For example, Benetton and Zara, the Italian and Spanish clothing companies, have been particularly effective at integrating innovation in products, operations, marketing, and sales, allowing them to achieve their competitive aims of quickly delivering ever-changing fashion goods to market. They can deliver 'fast fashion', ensuring that what Madonna wore at her Saturday-night concert is in the shops the following Wednesday.

A NATIONAL PERSPECTIVE

The ability to manage innovation matters at national, regional, and local levels because it has implications for overall levels of employment, the types of work people do, and the ways in which countries, regions, and cities prosper or decline. Globalization of production and markets, together with increased use of digital communications and services, have led to significant restructuring of whole economies and the ways in which innovation processes are managed on a local and international scale. Nevertheless, there remains a strong spatial dimension to the management of innovation processes (Morgan 2004). Nations still matter for innovation.

Empirical research findings showing the importance of technological innovation include:

- High-technology industries grew more than two-and-a-half times faster than manufacturing industry as a whole between 1980 and 2003 (NSB 2006).
- Trade in high-technology goods (requiring high levels of R & D) doubled in real terms in the OECD countries between 1994 and 2003 (OECD 2005).
- High-technology industries in the USA increased from 11 per cent of domestic production in 1980 to 13.5 per cent in 1990, and to 34 per cent in 2003 (NSB 2006).
- Innovative countries and regions have higher productivity and income than the less innovative ones (Fagerberg 2005).
- The returns to R & D investment, both 'social' (to society as a whole), and 'private' (to the firm making the investment), are consistently assessed to be high. In a study of seventeen innovations, Mansfield et al. (1977), found the social returns from R & D investment to be 56 per cent, and private returns to be 25 per cent.
- Technological innovation has played a significant role in the economic transformation of the East Asian economies (Kim and Nelson 2000).
- Entire industries, such as the Swiss watch industry, and geographical regions, such as Silicon Valley in California, can be invigorated or depressed by technological change (Saxenian 1994; Utterback 1994).

- At the corporate level, new products less than five years old are estimated to account for 30 per cent of the profits of US firms, and in high-performing firms to account for nearly half of sales and profits (Cooper and Edgett 2007).
- Innovative firms are more likely to be granted credit and easy access to finance than non-innovators (Czarnitzki and Kraft 2004).
- In the UK, innovators in both the service and manufacturing industries have higher productivity and productivity growth than non-innovators (Criscuolo, Martin, and Haskel 2003).
- Technology licensing and royalty payments increased in constant prices from \$7 billion in 1976 to over \$120 billion in 2004 (World Bank 2006).

A THEORETICAL PERSPECTIVE

Empirical findings on the significance of technological innovation are reinforced by new theoretical approaches, which reveal the importance of innovation, particularly evolutionary economics and new or endogenous growth theory (see Box 1.3).

Box 1.3 Evolutionary economics

The importance of technology for economic development has been well understood by political economists from Adam Smith to Karl Marx to Alfred Marshall, but it was Joseph Schumpeter who first placed innovation centrally in his economic analysis. For Schumpeter, innovation—defined as new products, methods of production, sources of supply, markets and ways of organizing—explained how economies grow: '[N]othing can be more plain or even more trite common sense than the proposition that innovation... is at the center of practically all the phenomena, difficulties, and problems of economic life in capitalist society' (1939: 87). Capitalism was understood by Schumpeter to be continually dynamic and evolving, and this dynamism was caused by more than firms simply responding to price signals in the market. Notions of equilibrium in economic models are considered to be transient rather than automatic. Evolutionary economics sees capitalism as a system that creates continuous variety—new ideas, firms, and technologies created by entrepreneurs and the innovative activities of large research groups (Nelson and Winter 1982, 2002; Dosi 1988; Metcalfe 1994, 1998; Nelson 1995). Selection processes choose from that variety through the decisions for firms, consumers, and governments. Some of these market selections are successfully propagated and are fully developed into new firms, businesses, and technologies that provide the basis for future investments in creating variety. Much of the variety and selections that occur are disruptive or fail to be propagated, so the evolutionary development of the economy is typified by significant uncertainty, disruption, and failure. From an evolutionary economics perspective, success in innovation explains the differential performance of nations, regions, and businesses.

Contemporary evolutionary economic theory (Andersen 1994; Dopfer and Potts 2007; Frenken 2000) continues to argue that economic growth and development is first and foremost a consequence of innovation, and it brings additional insight from complexity theory. Economic growth is an enormously complex process, involving multiple parties in open systems with resultant unpredictable outcomes. Innovation brings profits, but it also brings structural change (Schumpeter's 'creative destruction'), uncertainty, and 'wasted' investments.

The implications of evolutionary economics for MTI lie in the way it helps explain the central importance of innovation, yet shows that innovation is complex and uncertain and typified by failure. It highlights the central paradox of innovation: that it is essential yet continually problematical.

Box 1.4 Major features of new growth theory

- Technology is 'endogenous'—a central part of the economic system, a key factor of production along with capital and labour.
- Although any given technological breakthrough may appear random, technology overall increases in proportion to the resources devoted to it.
- Technology produces 'positive returns'. Traditional theory predicts diminishing returns to investment, yet sustained, robust growth can be achieved by technological investment.
- Investment can make technology more valuable and technology can make investment more valuable—a virtuous circle that can permanently raise an economy's growth rate.
- Monopoly power is useful in providing incentives to technological research (Schumpeterian rent).
- The emerging world economy is based on ideas rather than objects and this requires different institutional arrangements and pricing systems taking into account, for example, that prices depend on development time, cost, and risk not unit production costs.
- The possibilities for discovery and continual improvements are endless.

Traditional neoclassical economics considers technology to be an 'exogenous' factor in explaining economic growth: essentially it is taken as given. Simply put, this form of analysis believes that productivity and growth are a function of combinations of the three productive factors: land, labour, and capital, with a large unexplained residual in the calculations. In this body of theory, technological innovation may be part of the explanation for this residual, but there is little concern to establish its importance. The sources of technology and the distinctive and idiosyncratic ways innovation is used in individual firms to create growth are ignored. Furthermore, technological investments, such as all capital investments, are assumed to produce declining returns over time (Verspagen 1993).

In contrast, new growth theory argues that technology is an important 'endogenous' factor explaining growth, and comprehension of the way technology flows between firms and industries is essential (Romer 1990), (see Box 1.4). Additionally, unlike conventional investments in plant and equipment, which generally have declining returns over time, technological investments are argued to produce positive returns through creating new knowledge, options, and opportunities (Arthur 1990).

AN INDIVIDUAL PERSPECTIVE

The contribution to society of past and current innovators, such as Edison, Marconi, Steve Jobs at Apple, and Bill Gates at Microsoft, are well known and celebrated. But as we shall see throughout this book, innovations do not just occur through the heroic efforts of individuals; they most commonly result from the combined activities of groups of people and organizations building upon each other's knowledge and experience. The work they undertake may entail more of Edison's '99 per cent perspiration', than his '1 per cent inspiration', and indeed occasionally may be, as Nathan Rosenberg (1976) puts it 'grubby and pedestrian'. Yet innovation is the result of the application of innate human inventiveness and ingenuity. As we shall see in Chapter 6, creativity is something that everyone is capable of, and the application of the innovativeness of all of us is a source of excitement, challenge, satisfaction, and happiness.

The challenges of MTI

The more the focus of innovation activity moves away from simple incremental improvements towards more demanding changes, and the greater the number of players engaged in its creation, the more MTI involves trying to manage something that is *complex* and *risky*. In addition to the intrinsic complication of many products and services, a key aspect of complexity lies in the systemic nature of contemporary business. Complexity in this sense is defined as having emergent properties: it is characteristic of systems that have multiple contributors and unpredictable outcomes. Furthermore, technology-based innovations, be they aeroplanes, cars, buildings, home banking, or mobile phones, are comprised of various component systems. Computers, for example, comprise central processing units, operating systems, applications software, disk drives, memory chips, power supplies, and communications devices, including keyboards and screens. The integration of these often highly complicated systems is a key MTI task.

Some of these complex systems have been described as a particular form of industrial production, requiring different management approaches (Hobday 1998). Thus, for complex products and systems (CoPS; including high-value products, capital goods, control systems, networks, and engineering constructs, such as aircraft engines, avionic systems, offshore oil equipment, and intelligent buildings), there are particular requirements for design, project management, systems engineering, and systems integration (Brusoni, Prencipe and Pavitt 2001).

Levels of risk are determined by a number of factors, including the extent to which innovation outcomes are unpredictable, costly, and appropriable. The innovative activities of firms, for example, are confronted by general *business* uncertainty of future decisions on investment; *technical* uncertainty about future technological developments and the parameters of technological performance and cost; *market* uncertainty about the commercial viability of particular new products or processes (Freeman and Soete 1997). With the high degree of risk and uncertainty of investments in technological innovation (see Chapter 3), and the very high levels of investment in it (some firms spend billions of dollars annually on R & D, and some industrial sectors, such as electronics and pharmaceuticals, spend over 10 per cent of annual sales income on R & D), there are enormous pressures internationally on firms to reduce the costs of technological innovation or to get better returns from it.

There are challenges associated with all the methods used to ensure desired returns to innovation investment, such as whether intellectual property protection is awardable and can be maintained, or secrets can be kept. They explain why innovators so often fail to appropriate returns to their efforts, an issue examined in Chapters 3, 4, and 9. An additional consideration is the question of speed: how quickly can innovation be protected and returns achieved? New markets can develop very rapidly on the basis of new technology. In the decade since its development, it is estimated that global electronic commerce has become a trillion dollar business. Operating in such fast-changing environments poses challenges for many firms, but also opportunities for others.

Whether applied to developing or improving new products, processes, and services, MTI requires the *organizational ability to learn fast* and move quickly when winning notions emerge. As we shall see in succeeding chapters, firms develop organizational rigidities and can become averse to innovation and to external sources of ideas. All these challenges of MTI—complexity, risk, and learning—will be examined in this book.

Case studies in MTI

Some of the aspects, issues, and common problems of MTI are briefly illustrated in the following short case studies, which are composite descriptions of actual companies highlighting the opportunities and issues they face.[1]

THE US BIOTECHNOLOGY FIRM

The biotechnology firm emerged in the late 1970s in the USA. These firms began as vehicles for transferring new scientific discoveries in genetic engineering and immunology into industry, from government research laboratories and universities. Some firms were

[1] The description of the case studies derives from a number of research projects conducted by Mark Dodgson. The pump firm case derives from a research project in the British pump industry conducted by Professors Ron Dore and Hugh Whittaker. The Japanese electronics firm case is based on a study of the Japanese multimedia industry conducted with Professor Mari Sako, and research into a major Japanese electronics company in Singapore. The biotechnology example was based on a study of Celltech and the biotechnology industry. The Taiwanese case is based on numerous research visits to Taiwan, encompassing both large and small firms, and ITRI. Dodgson acted as advisor to the Taiwanese National Science Council's research programme in the machine-tool industry. The Indian software company case was based on a number of research visits to India and particularly to Bangalore, and on a case study of the international technology strategy of Ericsson. The Mexican study encapsulates some of the issues raised in the special edition of *Innovation: Management, Policy and Practice* (2005) on innovation in Latin America edited by Gabriela Dutrénit and Mark Dodgson.

initially expected to follow the pattern of the IT industry and duplicate the remarkable growth of firms such as Apple, Intel, and Microsoft. Few biotechnology firms, however, have grown to reach any size; many have been acquired by large pharmaceutical firms, and those that remained independent have focused mainly on product development, rather than becoming integrated producers and distributors.

Sidmuth Gene Technology (SGT) is an example of a US biotechnology firm seeking the best way of delivering value from its intellectual property. The company is based in Cambridge, Massachusetts, and employs forty-five people, including twenty Ph.D. scientists, in the development of gene technology repressing the growth of liver cancer.

SGT was started by two scientists, Elaine Weissman and Peter Georghiou, and a venture capitalist, Jenny Kuper, on the basis of a scientific discovery with two potential market applications. Laboratory tests had proven very successful, and Weissman and Georghiou believe their discovery would contribute to overcoming liver cancer, a disease that has produced a multimillion-dollar market in the USA.

The challenges facing SGT are considerable. They include managing the regulatory process needed to first, protect, and second, to develop its discovery. The company patented its discovery (which was the basis of Jenny Kuper's original investment), but there were a number of technical aspects allied to the major discovery that were not fully patented. This was due a certain naiveté on the part of the directors of the new company, and a concern to control the costs of patent registrations. Subsequently, SGT discovered that the real commercial value-added of its discovery lay not in the substance itself (a complex protein), but in the process of scaling-up and manufacturing the product. This process is delicate, involving growing the product in quantities of a few grams, using the medium of a specific animal gene. Considerable intellectual capital had been invested in developing this production process, but it had not been patented, and competitor firms had mastered the technology because Weissman and Georghiou had continued their academic tradition of publishing and discussing their research findings. Although the company knew it was in the knowledge-selling business, it failed to recognize which aspect of its knowledge was most valuable.

A second problem facing SGT is the amount of time and money it takes to gain approval for the development of a new drug. In the US regulatory system, it can take between 4 and 14 years, and cost in excess of $750 million to secure approval for a new drug, due to the strictly controlled testing and approval process involved. SGT had initially focused on developing one of the two potential applications. It found, however, that although the new product worked, it did not perform demonstrably better than existing products in the marketplace. So they turned their attention to the second application, and this involved considerable delay and increased cost.

SGT could not possibly afford to proceed through the regulatory process of drug approval by itself, nor could it attempt to develop the huge marketing and distribution effort required to bring its products to market. It had initially thought that its potential product was so efficacious that it would be sold on prescription in pharmacies, but subsequently had decided that greater supervision of use was necessary. It explored the possibility of targeting specialist care in hospitals. Weissman and Georghiou thought that whereas in the first case SGT would have had to sell the product rights to a large company that could afford the cost of marketing and distribution, in the second it would be able to retain some rights to the product. The cost of commercializing the product in this way, however, also proved prohibitively costly. To improve its cash flow, it had begun offering research services to other companies, using the expertise of its staff and its scientific equipment to analyze and sequence various genetic materials. After much debate and with some reluctance, it entered into a strategic alliance with a major US pharmaceutical company, receiving substantial investment capital in return for all rights to the developed product.

The management challenges facing the biotechnology firm's three directors are therefore considerable. The two scientists, rather than doing research, find their time consumed with liaising with regulatory bodies, and dealing with patent infringements and the drug approval process of the US Food and Drug Administration, performing routine procedures to assist cash flow, and managing the sometimes difficult and demanding relationship with the large partner pharmaceutical firm. Weissman and Georghiou want to maintain the excitement and desire for discovery in the company, and encourage the creativity required for continuing new product development and the building of the firm's knowledge base. Jenny Kuper had achieved considerable success in the computer industry, but had little experience of the pharmaceutical business. Her expectations of fast returns have not been fulfilled, and she is undecided about her exit strategy. She could continue to bankroll the company in syndication until other products are developed, or nearly developed, and then sell the company in an Initial Public Offering (IPO), potentially making very substantial returns. Or she could continue to encourage SGT to sell its intellectual property at a much lower return to a larger pharmaceutical firm, exposing herself to less risk.

The company faces important strategic decisions about its future. It could become a research services company, but where is the fun for creative scientists in that? It needs to decide whether to continue to fund its own expensive research to develop a pipeline of new products, or whether to be very ambitious and attempt to develop and market its own products, perhaps in collaboration with other firms. It has to consider whether to sell out to a pharmaceutical company, and if so at what stage it should attempt to do so.

THE MEXICAN AUTOMOTIVE COMPONENT SUPPLIER

Mexico's *maquiladoras* are primarily manufacturing assembly firms. They enjoy the tariff advantages of duty-free importation of materials, provided goods are then exported back into the USA (which in turn offers favourable tariffs compared to other countries). The *maquiladoras*, which have been an extremely important part of Mexican industry since the 1960s, have been facing severe cost competition from East Asian countries, and especially Thai firms.

Camino is a *maquiladora* supplying electronic circuitry to the US automotive industry. It is an example of a company wishing to move up the supply chain by providing more value-added products through innovation. It employs 120 people in the Jalisco region, and has been in operation since 1985. Traditionally the roughly 3,000 *maquiladoras* in Mexico compete on the basis of low costs and low skills, but many are upgrading their skill base.

Camino is owned by a married couple. Gabriela Camino has 20-years experience in marketing for CEMEX, one of Mexico's largest companies and a global supplier of building components, products, materials, and solutions. Rodrigo Camino is an electrical engineer with an M.Sc. in management, who has worked for a number of US multinationals in Mexico City. The couple decided they had had enough working for other people and also wanted to return to their home town of Guadalajara. They foresaw a business opportunity to upgrade a factory in need of investment, which would allow Rodrigo to pursue his ambition of developing a new kind of lighting system based on a circuit board design he had been working on for several years. They bought the company, renaming it in 1999.

The first challenge for Camino was to improve the machinery and quality control systems in the company, but Gabriela and Rodrigo recognized this was not by itself sufficient to support their ambitions. The company has a strategy of rapid technological upgrading, including the development of design and R & D capabilities.

The key component of this strategy is collaboration with other local suppliers and several of Jalisco's seventeen universities. It has involved extensive discussion with senior faculty in university engineering departments on skills requirements, industrial project placements for students, and collaborative research projects. Camino is keen to recruit more graduate electronic engineers with good design and project management skills. It has also recruited more than thirty technicians to operate and maintain its computerized machine tools. Creating the scale of resources necessary to invest in worthwhile research projects is beyond the budget of individual firms, and the Caminos have been highly active in creating a local industry support network allowing research projects with common applications to be explored, articulated, and funded. The network works closely with the Jalisco Quality Institute to help improve quality certification, Jaltrade (Jalisco Foreign Trade Institute) to support its exports, and Fojal (Jalisco Fund for the Promotion of the Enterprise) to access credit lines, training, and technical assistance. The regional government has been an active supporter of the network and always ensures that visiting trade delegations visit one or more of its members.

One of the major challenges for Camino is gaining the confidence of US customers that as well as providing high-quality production capabilities, it is a source of innovative products. Gabriela's marketing experience is valuable here, and she is a regular attendee at automotive industry trade shows, but the company has also cleverly used Internet-based innovation portals to demonstrate its capabilities. Several car manufacturers, and their top-tier suppliers, use Internet-based innovation markets to buy and sell technology (see Chapter 9 for a description of one such). Rodrigo has astutely observed the postings of technology requirements for automotive lighting, and constructed a portfolio of solutions developed by him, to demonstrate the company's design competence. The provision of several successful solutions has brought some very welcome additional investment funds into Camino. As some of these solutions have involved using instrumentation and resources at local universities, the company has been very careful to ensure that these universities receive appropriate remuneration. The latest technological solution provided by Camino received a certificate of commendation from Ford, which now features prominently in the company's marketing literature.

The Camino's strategy is based upon the development of highly reliable production and operations capabilities delivering quality components. They believe that this will provide a reputational platform from which they can offer their more innovative products. Should Gabriela manage to persuade a major automotive supplier to buy Camino's innovative lighting system, it will need to know that delivery can be guaranteed, either from Camino or its network of local companies.

THE TAIWANESE MACHINE-TOOL COMPANY

Taiwan has a thriving machine-tool industry, encouraged by supportive government policies. Machine tools are a key industrial technology. They make up the components of other machines, including, of course, the parts of which they themselves are made. They perform the various processes involved in cutting metals and other materials, such as milling, turning, drilling, and boring. These processes are highly computerized, ensuring high quality and standardization. They are also increasingly complicated in the extent to which they are integrated into other aspects of manufacturing. In planning, factories operate using shared databases controlling production sequences and linking design and production. In production, machine tools are linked with robots and automated transfer mechanisms in flexible manufacturing systems.

Li Ping Machine Tools is an example of a company searching for innovative products and designs. Established in 1964 in Kaosiung in the south of Taiwan, Li Ping employs 250 people producing computer-controlled machine tools. Its products are used in the manufacture of sophisticated gears and valves for the automotive, chemical plant, and aerospace industries.

Li Ping began by producing traditional, non-computerized machine tools to turn simple components for the domestic bicycle industry. The founder of the company sent his son, Tim Zhang, to study engineering in the USA. After staying on to complete his MBA and to work for a few years for a supplier to the US aerospace industry, Zhang returned to Taiwan and immediately set about upgrading the company's technology and product range. He invested heavily in new design technologies and databases and embarked on a strong export drive assisted by favourable loans from the government. Zhang introduced computer control of the machine tools, purchasing the components from a Japanese supplier. He improved the design and functionality of the products so that they could perform several machining functions, by working closely with the Industrial Technology Research Institute (ITRI), a government research agency. ITRI receives funds from the Taiwanese government to develop the machine-tool industry and had assiduously collected information about technological advances around the world. It had created a research group in Taiwan, which undertook collaborative research projects for machine-tool producers, and Li Ping participated in and helped direct the technical aims of a number of them.

The company recruited a number of first-class researchers and engineers working in the USA and Europe to help with these developments, including a very talented industrial designer, Sarah Chen. Li Ping's interest in design was influenced by Tina Chou, Tim's wife, who has a background in the clothing industry and had completed a course in computer-aided design (CAD) during her studies at the London School of Fashion. The company's recent investments have been in advanced product management systems and software, which enable it to store and retrieve design data, to prototype virtually, and integrate more closely with its suppliers.

Tim Zhang faces a number of challenges. First, the imported Japanese computer and software component of the product is becoming an increasingly important element of the product's cost. A fluctuating Yen, and an inability to control supply, has made the company keen to produce the computer controls domestically; however, it lacks expertise in this area.

Second, competition in the standard machine-tool market has intensified. The demand in export markets and in Taiwan lies in highly sophisticated machines capable of cutting new materials to extraordinarily high precision, in production contexts ranging from the aerospace industry to the increasingly sophisticated bicycle industry. The company needs to develop expertise at the forefront of the interfaces between mechanical and electronic engineering. It requires access to basic scientific knowledge about complex mathematical calculus and the properties of new materials. It also needs to consider possible entry into the emerging field of additive technologies, such as rapid prototyping, which build parts layer-by-layer, rather than machining them to shape. The company has performed superbly in catching up with world's best practices and is now at the technological forefront. Its future competitiveness depends on developing technological leadership and managing the substantial risk this involves. In addition, ITRI, although helpful in the beginning, is less capable of assisting a firm at the technological frontier. The current system of government support would need to change radically in order to continue to assist Li Ping and similar firms.

Li Ping has many challenges to deal with. Should it acquire one of the many innovative local computer companies and focus it on machine-tool controls? Or should it collaborate with a local computer company in developing its own control system?

Zhang is convinced that a key element in the solution to the problems he faces lies in the creation of highly autonomous and creative new product development teams. This is a rather radical departure in a traditionally hierarchical organization, and would require considerable cultural change. In his view these teams would be able to quickly design and deliver new options for the firm, ahead of competitors. He believes he has the necessary engineering skills within the firm to be able to absorb and use new scientific and technological information. He knows that in Sarah Chen he has a designer who is capable of leading projects that will produce tools that will be very attractive to customers. His challenge is to foster efficient teamwork linking research, development, operations, and marketing to make sure that the speed of response to new opportunities exceeds that of his competitors.

THE JAPANESE MULTINATIONAL COMPANY'S CORPORATE R & D LABORATORY

Japanese electronics was one of the industrial success stories of the second half of the twentieth century. Throughout Japan's development, from catching up with the industrialized economies after the Second World War to its present position of international technological leadership in many fields, its firms have engaged in substantial R & D. Most Japanese electronics firms support centralized R & D laboratories close to the corporate headquarters.

Ohsaki Electronics is an example of a major multinational company rethinking the role of its corporate R & D laboratory. The company is part of a conglomerate with business operations in fifty countries, whose divisions produce consumer electronics, industrial power systems, heavy plant and equipment, hotel and retailing services, and office equipment. Its present governance structure was created in the late 1940s. Ohsaki is one of the world's most successful consumer electronics companies. It spends nearly $3 billion on R & D each year, mostly on the company's fifteen decentralized divisional laboratories. Around 10 per cent of the company's total R & D spending is allocated to the central laboratory—Ohsaki Electronics Laboratory (OEL)—which employs 400 people in Japan and 120 overseas, and has responsibility for longer-term research, defined as having expected outcomes beyond five years.

OEL has been successful in providing scientific support to the company's divisional research functions, and its researchers are highly productive, measured by the number of academic publications and patents produced. It has successfully contributed to the development of the firm's technological base.

Masao Yamamoto, OEL's Director, is facing a number of conflicting pressures. He has to extend the range of expertise in the firm to meet the technological requirements of the businesses he supports. At the same time, because of adverse macroeconomic circumstances, his budget is being reduced and he is under strong pressure to speed up the returns to research efforts. The core areas of science underpinning the company's activities are becoming broader and therefore less controllable, and he no longer has the breadth of knowledge in his staff, or the range of scientific equipment, required to undertake the research he considers necessary. He understands the reasons for the firm's desire for faster results from its R & D investments, but knows OEL's major contributions to the company in the past have been through longer-term, more basic R & D.

The expertise required by OEL ranges from abstract theoretical particle physics to the development of new generations of embedded software. Its overseas research laboratories are linked to universities with particularly advanced expertise in these areas. While this system is working quite well in searching for and bringing excellent information back to Japan, Yamamoto is concerned that OEL may be locked into some rather inflexible university relationships. He is also worried about whether the lab is missing out on the potential of research conducted in emerging collaborative e-science networks and he has difficulty managing the international R & D labs. Their culture is different from that found in Japan, and tends to be much less hierarchical with a greater focus on individual creativity. He is also apprehensive about maintaining sufficient levels of expertise within his organization to be receptive to the wide range of inputs he needs.

Yamamoto's major challenge lies in converging the laboratory's mission of undertaking basic research with the greater demands he is facing for quicker returns to the Ohsaki's investment. He knows there are many instances of disruptive technologies emerging with the potential to threaten existing business strengths, but appreciates that in the present economic conditions Ohsaki's focus is getting the best returns from current investments. He is also under some pressure from within his company and from his contacts in the Japanese government to increase the amount of work with local universities, whose scientific expertise in required areas is gradually increasing, but is still some way behind that found elsewhere.

Discussions are taking place at board level in Ohsaki about securing funding for longer-term R & D investments. As part of this process, Yamamoto has been encouraged to explore new methods for justifying and measuring the returns to R & D projects, and for making earlier decisions about which projects to support or terminate. There is continual pressure from the board to improve R & D productivity.

One opportunity Yamamoto sees for achieving this lies in collaborative and subcontracted R & D. OEL has been engaged in a number of Japanese government-sponsored collaborative R & D projects, with varying degrees of success. While his staff have been uncomfortable sharing scientific research with companies with which they vigorously compete, experiences of working collaboratively with smaller overseas firms, which are generally much quicker at commercializing basic research, have been very positive. Yamamoto is also aware of the potential of a number of highly specialized local small research and software firms, whose creativity he wishes to access. He is aware, however, of the dangers of imposing Ohsaki's large-firm management controls and reducing the distinctive advantages brought about by partners' flexible, unbureaucratic structures and incentive systems, despite the management problems that such structures would pose for him.

THE INDIAN SOFTWARE COMPANY

Located in several major cities, such as Bangalore and Hyderabad, the Indian software industry has grown over the last 20 years to be an international leader in software production. Indian software engineers are renowned for their high technical skills and comparatively low labour costs. It is these attributes that attracted companies, such as Microsoft, IBM, and Intel, to make substantial investments in India.

Bangalabad Systems is an ambitious, young, Indian software company seeking the best way to realize its plans for growth. The company is 10 years old and employs eighty-five people, only ten of whom are over 35. It works as a 'software factory', writing millions of lines of code as a systems-software subcontractor, mainly for a number of US and European firms and for two locally based companies. Orders come in with highly specified requirements, and the company writes the code on a jobbing basis, mainly using computer-aided software engineering tools.

Banglabad was started by two brothers, both graduates of the prestigious Indian Institute of Technology. Jajesh Chakravarti worked as a programmer for a large German electronics company in India while his brother, Kumar, worked for a number of years as a software engineer for a major US software company. They inherited some family money and decided to start a company together. The company then recruited a chief executive, Nitin Shah, a relative and an experienced manager from a Canadian telecommunications company.

The company is based in Bangalore. The decision to locate there was made primarily on the basis of the city's large labour market for programmers and software engineers. Many multinational IT companies are based there. Furthermore, and importantly, its lower levels of pollution and traffic congestion mean that the general working environment is more agreeable than many Indian cities. Bangalore is famous for its nightlife and bars—an important draw for the young workforce.

One of the company's major selling points is its strict adhesion to quality management. As a legacy of Jajesh's association with the German company, a large amount of time and resources have been dedicated to winning ISO 9000 approval from the International Organization for Standardization (ISO). The company is one of the few in Bangalore to hold all relevant ISO quality management approvals.

At first sight, the company is doing well. It is profitable and has good relationships with its customers. But the Chakravartis are worried about meeting their very high aspirations, and these concerns led them to appoint Nitin Shah. One of the major problems confronting the company is a tightening labour market. Salaries are increasing rapidly, and good software engineers are now in a position to pick and choose among employers. Whereas a few years ago salary level was the primary consideration for employees, recently the company has been losing employees to other companies offering more interesting and varied work and greater leisure time, which has also made it more difficult for it to recruit new staff. The profit margins of the company are becoming squeezed, and the company's largest client has opened a software company in China, where salary levels are significantly lower.

A second problem lies in the rapid growth of the company. Neither of the Chakravarti brothers has managerial experience or training. Although the business has been successful in the past based on its excellent project and quality management skills, the brothers admit that they have 'flown by the seat of their pants' in other areas, such as marketing and human resource management.

Nitin Shah is aware of these challenges and thinks that the company's future depends upon managing collaborative development projects. He believes that software subcontracting of the sort the company has been involved in the past is a 'race to the bottom'. Prices and margins will continue to be squeezed. He knows that competitiveness depends on attracting the best and brightest workforce, and wants the company to be attractive to the most talented and creative local employees, but is aware that he will never be able to recruit all the clever programmers that Banglabad needs.

His business strategy has two elements. First, he plans to start selling applications software services to companies in the telecommunications industry, a sector he knows well. The company has experience in working in open, client-server, architectures and he feels it can produce software that will fit seamlessly with customers' current environments. He needs to identify the best-possible collaborators to work with, a major issue given the great size difference between his firm and his customers. Second, he realizes that the company's project management skills give the firm the opportunity to coordinate other local subcontractors to create significant scale in software writing projects. Here the company's edge derives particularly from expertise in using capability maturity module (CMM), a package developed to measure how effective a software organization is in managing software projects to budget, and its ISO quality approvals. In effect, he plans to position the firm as the prime contractor, coordinating a network of subcontractors.

Nitin's plans include reorganizing the workforce around key collaborative projects and promoting five of the highest-potential engineers to project management positions. He recognizes the need to develop a technologically aware marketing function. Previously, the company's marketing was reactive and domestic in nature. It now needs to become international and proactive in identifying and working with key clients. He needs to develop the management skills of the workforce such that it can manage both clients and its own new software products, and at the same time develop the 'network management' skills required to coordinate local software suppliers. The company also needs to continue and develop its effective use of such tools as CMM, as it expands its technological ambitions in collaborative projects.

THE BRITISH PUMP FIRM

The pump industry is well established in Britain, with a number of firms over a century old. It includes companies producing relatively simple products for irrigation projects in Africa, to highly sophisticated pumps used for oil exploration at great depths. Few firms have successfully diversified or grown to any significant size, and the industry has seen numerous company closures over the past decade.

Fuller and Gordon (F&G), a British pump firm, provides a classic case of a traditional manufacturing company and the changes confronting its managers. The company, established in 1875, is based in Huddersfield in the north of England and currently employs 550 people. It offers a wide range of specialized products for pumping industrial fluids, including some of the most highly corrosive and toxic currently in use.

The Managing Director, Joe Fuller, an engineer who has been with F&G all his working life, is very aware of the innovation challenges confronting his company. He remembers how 20 years ago innovation in the firm was driven by local sales representatives reporting customer dissatisfaction with a particular facet of the product. Occasionally, new products might have emerged from the R & D or engineering function of the firm, incorporating some improvement, which would prove attractive to purchasers.

Currently, Joe is confronted by a radically different and more challenging global competitive environment where innovation is the key to survival and growth. Cheap, high-quality pumps are available from lower-wage economies. Efficient pumps using lightweight materials and less energy are offered from a wide range of advanced economies, all with distributors or licensees in the UK. Competitors are experimenting with rapid prototyping technologies, the introduction of electronic sensors and controls, and the bundling of services around performance control and maintenance, providing customers with a whole new range of innovative choices.

To remain competitive F&G has to be exceptionally smart and strategic in its innovation activities. It must be intimately aware of customer needs; indeed, it may sometimes have to anticipate them. The company must consider how it might benefit from outsourcing some of its activities to lower-cost countries. It has to stay abreast of recent scientific and technological advances in new materials and designs, and it requires links with research groups in universities and research institutes to take on problem areas in pump technology, such as cavitation, which it cannot solve by itself. F&G has to decide whether and how it might add services to its traditional production offerings. In short, the company has to reconsider its business model around the use of innovation.

Since the 1980s, the company has invested in several generations of expensive CAD system to assist its design processes. These have been integrated with its production system to facilitate the efficient manufacture of its designs to the high levels of quality expected in the industry. On occasion in the past, substantial development work has gone into a product that subsequently the company was not able to manufacture as the cost of retooling the factory was prohibitive. Technological integration between design and production has alleviated this problem. Joe Fuller is aware of the advantages for the company from such past and any future technological investments, but he knows the challenges facing the company will not be solved by technology alone.

Fuller is sensitive to the need for the company's internal organizational processes to be highly efficient so that creative ideas are quickly acted upon. He believes speed to market will help the company establish a leadership position. In the past there have been miscommunications between design and production staff, leading to delays. He has to ensure that the different functions in the firm—marketing, engineering, production, distribution, and service—are well integrated so that they can respond to market demands and technological opportunities. And he has to find the necessary investment funds required to undertake investments in a flat market. He is also aware that many engineers in the firm believe that they have all the answers and are reluctant to work with external partners and sceptical of marketers.

This is a problem for Joe as the major challenge to F&G is the extensive changes to its market. Pumps are often components of systems in buildings, factories, power stations, and sewerage works. Customers require the firm to learn to integrate its products into the various systems of assemblers or contractors, sometimes overseas and often operating to different technical standards. The pump manufacturer must sustain continuous dialogue with the firms coordinating the creation of the systems—the systems integrators—to produce creative solutions. F&G must improve its capacity to integrate its CAD system with these firms through the sharing of databases and design practice. It is beginning to develop closer links with its suppliers in, for example, electronic control systems in order to be aware of any advantages to its customers that might derive from their developments. F&G sees its investment in CAD as providing the basis for it to develop skills in designing and integrating new product systems.

Joe Fuller has to decide whether F&G will remain a supplier of components or modules to these systems. Or, rather than being the passive instrument of the systems integrators, whose control over the system ensures them substantial profits from their negotiating strengths, whether it can become a systems integrator itself. Whatever direction the firm takes, Joe Fuller is aware that all F&G's activities must be driven by a clear strategy such that all efforts fit together to cumulatively develop a distinctive advantage over competitors in innovation. The firm has to establish a clear reputation in the marketplace for innovation as a component supplier or a systems integrator. It has to become an employer attractive to highly skilled, creative, and committed workers. He knows an international approach is needed for both market and technology as many customers and suppliers have overseas operations. Offshore production has to be considered as an option, even if it adversely affects employment in the home factory.

Summary and conclusions

This chapter has defined MTI, analyzed its importance, and illustrated some of its key elements. It has shown why MTI is a major contributor to the construction and maintenance of competitive advantage and the ways in which managers meet their objectives. Whether considered at a national or regional level, in a particular industry or firm or from the perspective of individuals, technological innovation and its effective management is important.

MTI includes the ways managers create and deliver value from innovation strategy, R & D, innovation in products, services, operations, and processes, and commercialization, within innovation networks and communities. These activities can be complex, involving technological and organizational integration, and risky, with high levels of uncertainty, concern to control costs, and manage appropriability. In all considerations of technological innovation, learning is essential and this is a major underlying theme of this book.

As our examples have shown, and as will become clear as the book proceeds, MTI is a broad-ranging and challenging process, and even companies that have been highly successful at it in the past are continually being confronted by new difficulties. These challenges range from the day-to-day operational issues of how to make supportive technologies, such as CAD systems and CIM (computer-integrated manufacturing), more efficient, or dealing with government agencies to meet regulatory requirements, or major strategic issues determining the future of the company. The British pump firm needs to make innovation a core element of its business strategy, develop its innovative capabilities, and reconsider its business model: should it become a systems integrator? The US biotech firm similarly needs to consider its business model and decide whether it becomes a research services company or an integrated pharmaceutical company or something in between—is it in the market for products or ideas? It also needs to manage its intellectual property more effectively. The Taiwanese firm must decide how it is going to access key technologies in the future, and develop design and new product development teams that can work quickly and effectively. The Japanese laboratory needs to reconcile its strategic, long-term function with short-term financial constraints and better manage its external and international relationships. The Indian software firm needs to decide how it is going to manage its future growth by producing more creative, higher value-added services in collaboration with international partners and local networks. The Mexican automotive supplier needs to upgrade its strong operations capabilities to offer innovative products, using Internet-based intermediaries.

The challenges of MTI can be seen to include far more than technological issues. They include managing organizational, financial, human resource, marketing, and collaboration issues. They also encompass major strategic issues, concerning the business models used to deliver value. Many of these challenges result from broader changes occurring in industry and business and it is to these that we now turn.