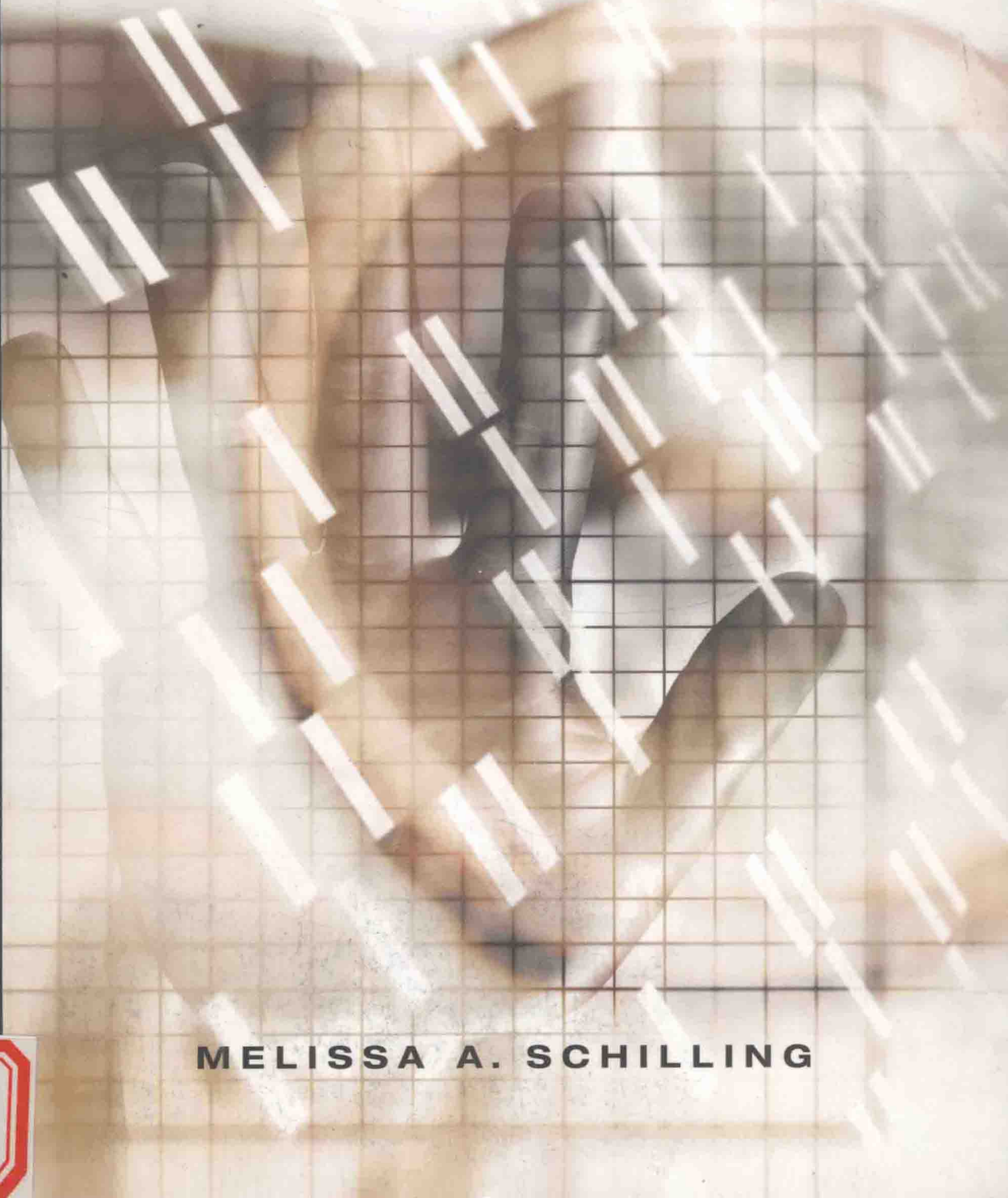
STRATEGIC MANAGEMENT of TECHNOLOGICAL INNOVATION



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Strategic Management of Technological Innovation

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Melissa A. Schilling is an associate professor of management at the Stern School of Business, New York University. Professor Schilling earned a B.S. in business from the University of Colorado in 1990 and a Ph.D. in strategic management from the University of Washington in 1997. She worked as an assistant professor for Boston University for four years before joining Stern. She recently won a National Science Foundation Early CAREER award that includes a grant to support her research for the next five years. She also won the Broderick prize for research while working at Boston University.

Professor Schilling's research focuses on technological innovation and knowledge creation. She has studied how firm's fight technology standards battles, and how they utilize collaboration, protection, and timing of entry strategies. She also studies how product designs and organizational structures migrate toward or away from increasing modularity. Her most recent work focuses on knowledge creation, including how variation (rather than specialization) can accelerate the learning curve, and how the structure of knowledge networks affects their overall capacity for knowledge creation.

Professor Schilling has published articles in a wide range of journals, including *Academy of Management Journal, Academy of Management Review, Management Science,* and *Organization Science.* She teaches Strategic Management and Technological Innovation Management in the undergraduate and MBA programs at the Stern School.

Preface

Innovation is a beautiful thing. It is a force with both aesthetic and pragmatic appeal: It unleashes our creative spirit, opening our minds to hitherto undreamed of possibilities, while simultaneously accelerating economic growth and providing advances in such crucial human endeavors as medicine, agriculture, and education. For industrial organizations, the primary engines of innovation in the Western world, innovation provides both exceptional opportunities and steep challenges. While innovation is a powerful means of competitive differentiation, enabling firms to penetrate new markets and achieve higher margins, it is also a competitive race that must be run with speed, skill, and precision. It is not enough for a firm to be innovative—to be successful it must innovate better than its competitors.

As scholars and managers have raced to better understand innovation, a wide range of work on the topic has emerged and flourished in disciplines such as strategic management, organization theory, economics, marketing, engineering, and sociology. This work has generated many insights about how innovation affects the competitive dynamics of markets, how firms can strategically manage innovation, and how firms can implement their innovation strategies to maximize their likelihood of success. A great benefit of the dispersion of this literature across such diverse domains of study is that many innovation topics have been examined from different angles. However, this diversity also can pose integration challenges to both instructors and students. This book seeks to integrate this wide body of work into a single coherent strategic framework, attempting to provide coverage that is rigorous, inclusive, and accessible.

The subject of innovation management is approached here as a strategic process. The outline of the book is designed to mirror the strategic management process used in most strategy textbooks, progressing from assessing the competitive dynamics of the situation, to strategy formulation, and then to strategy implementation. The first part of the book covers the foundations and implications of the dynamics of innovation, helping managers and future managers better interpret their technological environments and identify meaningful trends. The second part of the book begins the process of crafting the firm's strategic direction and formulating its innovation strategy, including project selection, collaboration strategies, and strategies for protecting the firm's property rights. The third part of the book covers the process of implementing innovation, including the implications of organization structure on innovation, the management of new product development processes, the construction and management of new product development teams, and crafting the firm's deployment strategy. While the book emphasizes practical applications and examples, it also provides systematic coverage of the existing research and footnotes to guide further reading.

This book is designed to be a primary text for courses in the strategic management of innovation and new product development. Such courses are frequently taught in both business and engineering programs; thus, this book has been written with the needs of business and engineering students in mind. For example, Chapter Six

(Defining the Organization's Strategic Direction) provides basic strategic analysis tools with which business students may already be familiar, but which may be unfamiliar to engineering students. Similarly, some of the material in Chapter 10 (Managing the New Product Development Process) on computer-aided design or quality function deployment may be review material for information system students or engineering students, while being new to management students. Though the chapters are designed to have an intuitive order to them, they are also designed to be self-standing so instructors can pick and choose from them "buffet style" if they prefer.

This book arose out of my research and teaching on technological innovation and new product development over the last decade; however, it has been anything but a lone endeavor. I owe much of the original inspiration of the book to Charles Hill, who helped to ignite my initial interest in innovation, guided me in my research agenda, and ultimately encouraged me to write this book. I am also very grateful to colleagues such as Juan Alcacer, William Baumol, Gary Dushnitsky, Tammy Madsen, Goncalo Pacheco D'Almeida, Raghu Garud, Bill Starbuck, and Christopher Tucci for their suggestions, insights, and encouragement. I am also thankful to my editors, Ryan Blankenship and Lindsay Harmon, who have been so supportive and made this book possible, and to the many reviewers whose suggestions have dramatically improved the book:

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I also need to thank my husband, Alex, for his love and support despite my neglect of him during the writing of this book. Finally, the biggest debt of gratitude is certainly owed to the many students of the Technological Innovation and New Product Development courses I have taught at New York University, Boston University, and University of California at Santa Barbara. Not only did these students read, challenge, and help improve many earlier drafts of the work, but they also contributed numerous examples that have made the text far richer than it would have otherwise been. I thank them wholeheartedly for their patience and generosity.

Melissa A. Schilling

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Chapter One

Introduction

THE IMPORTANCE OF TECHNOLOGICAL INNOVATION

technological innovation
The act of introducing a new device, method, or material for application to commercial or practical objectives.

In many industries **technological innovation** is now the most important driver of competitive success. Firms in a wide range of industries rely on products developed within the past five years for more than one-third of their sales and profits. For example, Baxter, a leading manufacturer of medical equipment and supplies, earned 37 percent of its 2002 sales from products introduced within the previous five years. The percentage of sales from products developed within the past five years has hit as high as 45 percent at 3M in recent years.

The increasing importance of innovation is due in part to the globalization of markets. Foreign competition has put pressure on firms to continuously innovate in order to produce differentiated products and services. Introducing new products helps firms protect their margins, while investing in process innovation helps firms lower their costs. Advances in information technology also have played a role in speeding the pace of innovation. Computer-aided design and computer-aided manufacturing have made it easier and faster for firms to design and produce new products, while flexible manufacturing technologies have made shorter production runs economical and have reduced the importance of production economies of scale.[1] These technologies help firms develop and produce more product variants that closely meet the needs of narrowly defined customer groups, thus achieving differentiation from competitors. A prime example is Sony, which produces more than 75 models of its Walkman portable stereo that differ in size, color, music format (e.g., MP3, minidisk, CD, cassette, radio signal), and other features. Sony's portfolio of Walkman models enables it to penetrate every conceivable market niche.[2] While producing multiple product variations used to be expensive and time-consuming, Sony uses flexible manufacturing technologies to seamlessly transition from producing one product model to the next, and to adjust production schedules with real-time information on demand. The company further reduces production costs by using common components in many of the models.

As firms such as Sony adopt these new technologies and increase their pace of innovation, they raise the bar for competitors, triggering an industrywide shift to shortened development cycles and more rapid new product introductions. The net results are greater market segmentation and rapid product obsolescence.[3] Product life cycles (the time between a product's introduction and its withdrawal from the market or replacement by a next-generation product) have become as short as 4 to 12 months for software, 12 to 24 months for computer hardware and consumer electronics, and 18 to 36 months for large home appliances.[4] This spurs firms to focus increasingly on innovation as a strategic imperative—a firm that does not innovate quickly finds its margins diminishing as its products become obsolete.

THE IMPACT OF TECHNOLOGICAL INNOVATION ON SOCIETY

If the push for innovation has raised the competitive bar for industries, arguably making success just that much more complicated for organizations, its net effect on society is more clearly positive. Innovation enables a wider range of goods and services to be delivered to people worldwide. It has made the production of food and other necessities more efficient, yielded medical treatments that improve health conditions, and enabled people to travel to and communicate with almost every part of the world.

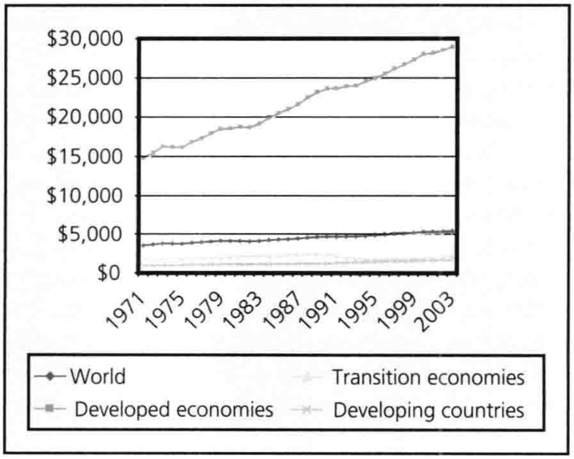
gross domestic product
The total annual output of an economy as measured by its final purchase price.

The aggregate impact of technological innovation can be observed by looking at **gross domestic product** (GDP). The gross domestic product of an economy is its total annual output, measured by final purchase price. Figure 1.1 shows the average GDP per capita (that is, GDP divided by the population) for the world, and also for developed economies, transitional economies, and developing countries, from 1971 to 2003. The figures have been converted into U.S. dollars and adjusted for inflation. As shown in the figure, the average world GDP per capita has risen steadily since 1971, particularly in the developed economies. Data dating to the 1920s for the United States show the same pattern.

In a series of studies of economic growth conducted at the National Bureau of Economic Research, economists showed that the historic rate of economic growth in GDP could not be accounted for entirely by growth in labor and capital inputs. Economist Robert Merton Solow argued that this unaccounted for residual growth represented technological change: Technological innovation increased the amount of

FIGURE 1.1
Gross Domestic Product per Capita, 1971–2003 (in 2000 $US)

Source: *Science and Engineering Indicators 2002*. National Science Board.



output achievable from a given quantity of labor and capital. This explanation was not immediately accepted; many researchers attempted to explain the residual away in terms of measurement error, inaccurate price deflation, or labor improvement. But in each case the additional variables were unable to eliminate this residual growth component. A consensus gradually emerged that the residual did in fact capture technological change. Solow received a Nobel Prize for his work in 1981, and the residual became known as the Solow Residual.[5] While GDP has its shortcomings as a measure of standard of living, it does relate very directly to the amount of goods consumers can purchase. Thus, to the extent that goods improve quality of life, we can ascribe some beneficial impact of technological innovation.

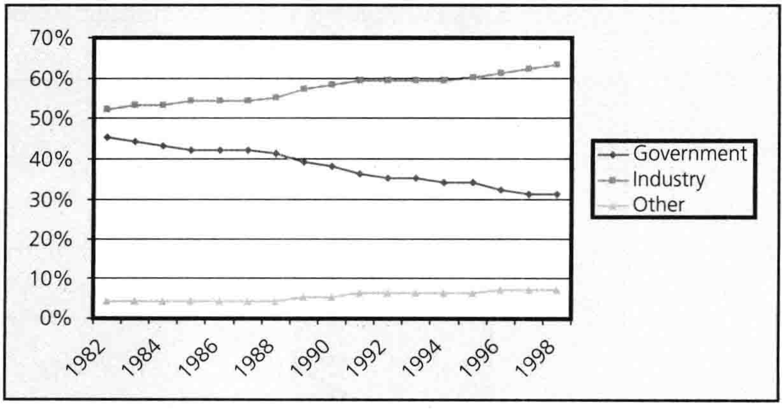
externalities
Costs (or benefits) that are borne (or reaped) by individuals other than those responsible for creating them. Thus, if a business emits pollutants in a community, it imposes a negative externality on the community members; if a business builds a park in a community, it creates a positive externality for community members.

Sometimes technological innovation results in negative **externalities**. Production technologies may create pollution that is harmful to the surrounding communities; agricultural and fishing technologies can result in erosion, elimination of natural habitats, and depletion of ocean stocks; medical technologies can result in unanticipated consequences such as antibiotic-resistant strains of bacteria or moral dilemmas regarding the use of genetic modification. However, technology is, in its purest essence, knowledge—knowledge to solve our problems and pursue our goals.[6] Technological innovation is thus the creation of new knowledge that is applied to practical problems. Sometimes this knowledge is applied to problems hastily, without full consideration of the consequences and alternatives, but overall it will probably serve us better to have more knowledge than less.

While the government plays a significant role in investing in technological innovation, among member countries of the Organization for Economic Cooperation and Development (OECD), the majority of R&D funds come from industry. Furthermore, the percentage of R&D funds that come from industry (versus government) has been growing at a quick pace (see Figure 1.2). These figures include R&D funds paid to university scientists and private research organizations, in addition to funds utilized within firms. The statistics indicate that industry bears much of the responsibility for technological innovation.

FIGURE 1.2
Percentage of R&D Funds from Industry, Government, and Other Sources, for OECD countries,* 1982–1998

Source: *Science and Engineering Indicators 2002.* National Science Board.



*OECD countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

INNOVATION BY INDUSTRY: THE IMPORTANCE OF STRATEGY

In the frenetic race to innovate, many firms charge headlong into new product development without clear strategies or well-developed processes for choosing and managing projects. Such firms often initiate more projects than they can effectively support, choose projects that are a poor fit with the firm's resources and objectives, and suffer long development cycles and high project failure rates as a consequence (see the accompanying Research Brief for a recent study of the length of new product development cycles). While innovation is popularly depicted as a freewheeling process that is unconstrained by rules and plans, study after study has revealed that successful innovators have clearly defined innovation strategies and management processes.[7]

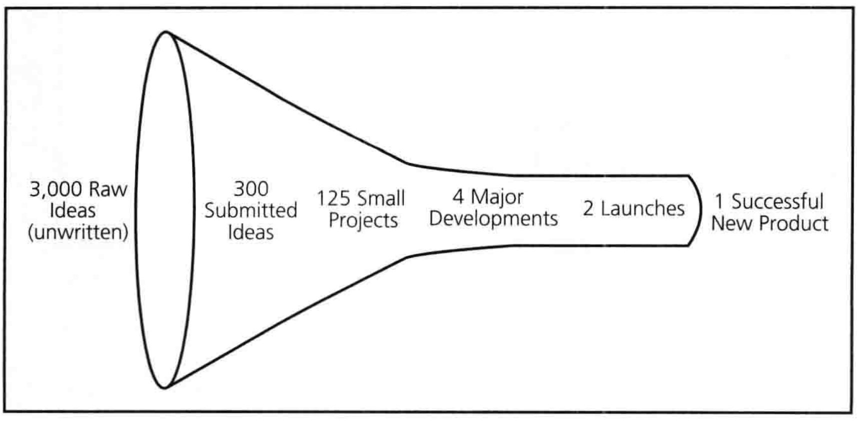
The Innovation Funnel

Most innovative ideas do not become successful new products. Many studies suggest that only one out of several thousand ideas results in a successful new product: Many projects do not result in technically feasible products and of those that do, many fail to earn a commercial return. According to one study that combined data from prior studies of innovation success rates with data on patents, venture capital funding, and surveys, it takes about 3,000 raw ideas to produce one significantly new and successful commercial product.[8] The pharmaceutical industry demonstrates this well—only one out of every 10,000 compounds succeeds as a new pharmaceutical, with an overall time from discovery to market of 12 years, and a total cost of approximately $350 million! The innovation process is thus often conceived of as a funnel, with many potential new product ideas going in the wide end, but very few making it through the development process (see Figure 1.3).

The Strategic Management of Technological Innovation

Improving a firm's innovation success rate requires a well-crafted strategy. A firm's innovation projects should align with its resources and objectives, leveraging its core competencies and helping it achieve its strategic intent. A firm's organizational

FIGURE 1.3
The Innovation Funnel



Research Brief How Long Does New Product Development Take?

In a study of 116 firms developing business-to-business innovations (that is, new products that are sold to businesses rather than consumers), Abbie Griffin examined the length of time it took firms to develop a new product from initial concept to market introduction. She found that the length of the new product development cycle varied with the innovativeness of the project. On average, *incremental improvements* to an existing product took only 8.6 months from concept to market introduction. *Next generation improvements* (large improvements to existing products) took significantly longer, clocking in at 22 months. The development of *new-to-the-firm product lines* took an average of 36 months, and the development of *new-to-the-world products* or technologies took the longest, averaging 53 months. Griffin also found that about half of the companies had reduced their cycle time by an average of 33 percent over the last five years.

Source: Adapted from A. Griffin, "Product Development Cycle Time for Business-to-Business Products," *Industrial Marketing Management* 31, pp. 291–304.

structure and control systems should encourage the generation of innovative ideas while also ensuring efficient implementation. A firm's new product development process should maximize the likelihood of projects being both technically and commercially successful. To achieve these things, a firm needs (*a*) an in-depth understanding of the dynamics of innovation, (*b*) a well-crafted innovation strategy, and (*c*) well-designed processes for implementing the innovation strategy. We will cover each of these in turn (see Figure 1.4).

In Part One, we will cover the foundations of technological innovation, gaining an in-depth understanding of how and why innovation occurs in an industry, and why some innovations rise to dominate others. First, we will look at the sources of innovation in Chapter Two. We will address questions such as: Where do great ideas come from? How can firms harness the power of individual creativity? What role do customers, government organizations, universities, and alliance networks play in creating innovation? In this chapter we will first explore the role of creativity in the generation of novel and useful ideas. We then look at various sources of innovation, including the role of individual inventors, firms, publicly sponsored research, and collaborative networks.

In Chapter Three, we will review models of types of innovation (such as radical versus incremental, or architectural versus modular) and patterns of innovation (including s-curves of technology performance and diffusion, and technology cycles). We will address questions such as: Why are some innovations much harder to create and implement than others? Why do innovations often diffuse slowly even when they appear to offer a great advantage? What factors influence the rate at which a technology tends to improve over time? Familiarity with these types and patterns of innovation will help us distinguish how one project is different from another and the underlying factors that shape the project's likelihood of technical or commercial success.

FIGURE 1.4
The Strategic Management of Technological Innovation