

1 The Strategy Challenge

At a time when national monopolies have been losing their secular well-protected positions owing to market liberalization in the European Union and elsewhere across the globe, strategic interdependencies and interactions have become a key challenge for managers in many corporations. Strategic questions abound: How should a firm sustain or gain market share? How to differentiate oneself from others in the grueling global marketplace? When precisely should a firm enter or exit an industry when it faces uncertainty and significant entry and exit costs?

Recent developments in economics, finance, and strategy equip management facing such challenges with a concrete framework and tool kit on how to behave strategically in such a complex and changing business environment. Corporate finance and game theory provide complementary perspectives and insights regarding strategic decision-making in business and daily life. Box 1.1 motivates the relevance of game theory to the understanding of daily life situations. The option games approach followed in this book paves the way for a more rigorous approach to strategy formulation in many contexts. It helps integrate in a common, consistent framework the recent advances made in these diverse disciplines, providing powerful insights into how firms should behave in a dynamic, competitive and uncertain marketplace.

We first highlight in section 1.1 several environmental factors that justify why firms should be careful when formulating their corporate strategies in an uncertain, competitive business environment. In section 1.2 we discuss how an understanding of competitive strategy in terms of sound economic principles is useful to managers. Two complementary but separate perspectives on strategy (corporate finance and game theory) are discussed in section 1.3. We address the need for an integrative approach to corporate strategy in section 1.4. We provide an overview of the book organization in section 1.5.

Box 1.1**Game theory in daily life**

All Is Fair in Love, War, and Poker

Tim Harford, *BBC News Online*

What Do Love, War, and Poker Have in Common?

High stakes, perhaps. Certainly, in all three you spend a lot of effort trying to work out what the other side is really thinking. There is another similarity: economists think they understand all three of them, using a method called “game theory.”

Threats and Counterthreats

Game theory has been used by world champion poker players and by military strategists during the cold war. Real enthusiasts think it can be used to understand dating, too. The theory was developed during the Second World War by John von Neumann, a mathematician, and Oskar Morgenstern, an economist. Mr. von Neumann was renowned as the smartest man on the planet—no small feat, given that he shared a campus with Albert Einstein—and he believed that the theory could be used to understand cold war problems such as deterrence. His followers tried to understand how a nuclear war would work without having to fight one, and what sort of threats and counterthreats would prevent the US and the Soviets bombing us all into oblivion. Since the cold war ended without a nuclear exchange, they can claim some success.

Understand the World

Another success for game theory came in 2000, when a keen game theorist called Chris “Jesus” Ferguson combined modern computing power with Mr. von Neumann’s ideas on how to play poker. Mr. Ferguson worked out strategies for every occasion on the table. He beat the best players in the world and walked away with the title of world champion, and has since become one of the most successful players in the game’s history. Game theory is a versatile tool. It can be used to analyze any situation where more than one person is involved, and where each side’s actions influence and are influenced by the other side’s actions. Politics, finding a job, negotiating rent, or deciding to go on strike are all situations that economists try to understand using game theory. So, too, are corporate takeovers, auctions, and pricing strategies on the high street.

Financial Commitment

But of all human interactions, what could be more important than love? The economist using game theory cannot pretend to hand out advice on

Box 1.1

(continued)

snappy dressing or how to satisfy your lover in the bedroom, but he can fill some important gaps in many people's love lives: how to signal confidence on a date, or how to persuade someone that you are serious about them, and just as importantly, how to work out whether someone is serious about you. The custom of giving engagement rings, for instance, arose in the United States in the 1930s when men were having trouble proving they could be trusted. It was not uncommon even then for couples to sleep together after they became engaged but before marriage, but that was a big risk for the woman. If her fiancé broke off the engagement she could be left without prospects of another marriage.

For a long time the courts used to allow women to sue for "breach of promise" and that gave them some security, but when the courts stopped doing so, both men and women had a problem. They did not want to wait until they got married, but unless the man could reassure his future wife, then sleeping together was a no-no. The solution was the engagement ring, which the girl kept if the engagement was broken off. An expensive engagement ring was a strong incentive for the man to stick around—and financial compensation if he did not.

Not Committed

Modern lovers might think the idea of engagement ring as guarantee is a thing of the past, but they can still use game theory to size up their partners. When a couple with separate homes move in together, selling the second home is an important signal of commitment. That second home is an escape route—valuable only if the relationship is shaky. If your partner wants to hang on to his bachelor pad, do not let him tell you it is merely a financial investment. Game theory tells you that he is up to something.

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1.1 The Changing Corporate Environment

The competitive environment around the globe is becoming increasingly challenging for managers as modern economies have witnessed tremendous changes over the last three decades. In this constantly evolving environment, where firms must often make quick decisions that have long-term impact, it is anybody's guess what might happen in the future—market developments often prove expectations wrong. Firms must carefully commit to specific strategies while developing adaptive capabilities

in an ever-changing marketplace. Globalization, deregulation, and the emergence of new economies (e.g., Brazil, Russia, India, and China) have created both threats and opportunities for incumbent firms who now have to adapt more effectively to the rapidly changing global environment or suffer damage by new entrants and risk extinction.

Following the liberalization and deregulation of European economies, only a limited number of industries have remained secure, while most companies across the board face serious competitive pressures. At the same time other economic sectors traditionally characterized by a large number of companies have undergone significant consolidation, resulting in oligopoly structures with a reduced number of players. The recent economic crisis has amplified these consolidation pressures. The mining giant Rio Tinto has recently merged with BHP Billiton, forming a virtual duopoly together with Brazilian mining giant Vale. M&A deals have similarly reshaped the automotive sector, with the recent acquisitions of Chrysler by Fiat, of Porsche and Suzuki by Volkswagen, and of Mitsubishi by PSA (Peugeot, Citroën). British Airways together with Iberia claim the top two position in the fiercely competitive European airline business. In the United States, the merger between United Airlines and Continental Airlines created one of the world's biggest airlines. A dramatic concentration has also taken place in the banking sector: out of the top five investment banks worldwide, only two (Goldman Sachs and Morgan Stanley) have remained independent. Notable banking deals include the acquisition of Washington Mutual by JP Morgan Chase, of Countrywide by Bank of America, and of the Belgian bank Fortis by BNP Paribas.

These two concurrent phenomena—liberalization and consolidation—have put higher on the corporate agenda the assessment of strategic uncertainty. Italy's dominant state electricity authority, Enel, is a good case in point. Just a decade ago Enel was in a very comfortable position, enjoying an established natural monopoly in the Italian electricity market with the benediction of the national government. The main concern for Enel during this period was to minimize or keep under control its mix of input or production costs, as the output electricity price was regulated. Several years later Enel lost its preferential monopoly position due to the liberalization of the European markets, and the competitive environment facing Enel changed dramatically. Enel was forced to sell half of its generating assets to half a dozen smaller local rivals, creating more competition in its home base. Electricity price deregulation accompanied by oil and other fuel price fluctuations have added considerable pressure

and uncertainty for Enel. With further deregulation other European competitors (e.g., the dominant electricity producer of France, EDF) also entered the Italian electricity market. Today Enel has to consider the actions of local as well as international competitors on the national soil, as well as contemplate investing itself in new or emerging markets, such as Russia, to sustain or leverage its once dominant position in the area. Just as its European and global counterparts, Enel now faces a broader range of uncertainties and challenges: How to cope with increased energy (input) and electricity demand (output) uncertainties? How to compete with local and global rivals in an ever-changing local and global competitive landscape? How to assure and diversify its energy portfolio mix in a globalized marketplace? How to formulate and dynamically adjust its strategy, knowing when to compete, threaten, bargain, or cooperate with its rivals? These are the kind of questions we will be addressing in this book.

Many situations corporate managers face today are characterized by both market and strategic uncertainty with respect to the economic environment. When one desires to address such complex issues, some simplification of reality is useful to focus on the fundamental trade-offs. Some simple models in management are being revised as they offer rather simplistic approaches that no longer describe current economic reality. The field of investment under uncertainty falls in this category. Prevailing management approaches often lead to investment decisions detrimental to the overall firm's long-term well-being. In an increasingly uncertain and competitive environment, corporate managers need appropriate management tools that can provide long-term guidance. This book describes a novel approach aimed to enable managers make rational decisions in a competitive environment under uncertainty. It allows managers to quantify and balance the conflicting impacts of managerial flexibility and the strategic value of early investment commitment in influencing rivals' strategic behavior.

Real options analysis is widely considered to be more reflective of reality than traditional financial methods (e.g., net present value) in that it takes managerial flexibility into account.¹ To avoid dealing with complex models, however, standard real options analysis often ignores

1. Investment under uncertainty is part of the mainstream literature on finance, economics, and strategic management. In the last decades financial theory has been supplemented with real options analysis. Use of the financial options analogue can be insightful in assessing flexibility embedded in real asset situations. The real options approach to investment has reached a corporate finance textbook status and is currently applied in leading corporations for guiding real-world strategic investment decisions.

the strategic interactions among option holders, analyzing investment decisions as if the option holder has a proprietary right to exercise. This simplifying perspective is far from being realistic in many situations because firms generally compete with rivals. Several firms may share an option in the industry and hence option exercise strategies cannot be formulated in isolation. Rather, optimal investment behaviors must be determined as part of an industry equilibrium. As a consequence of this more pragmatic view of the nature of the competitive environment, a new theory called “option games” has emerged. This theory combines the concepts and tools offered by traditional real options analysis with game theory principles designed to help figure out how players behave in strategic conflict situations. The option games approach we elaborate on herein provides powerful insights into understanding strategic interactions and challenges traditional thinking that presumes that firms pursue strategies in isolation. Game theory is for the most part deterministic. Option games help management better intuit how uncertainty can be modeled in a strategic setting. This approach helps improve prediction and understanding of industry dynamics in highly uncertain industries. It enhances previous industrial organization literature on strategic investment in a deterministic setting to better explain the strategic investment behavior of firms under changing conditions. Box 1.2 provides an overview of the challenges commercial airframe manufacturers

Box 1.2
Evolving strategy in commercial aviation

Boeing Bets the House on Its 787 Dreamliner

Leslie Wayne

In recent years Boeing has stumbled badly, ceding its decades-long dominance in commercial aviation to Airbus and becoming mired in a string of scandals over Pentagon contracts. The terrorist attacks of 2001 depressed demand at a time when the company’s product line paled against appealing new planes from Airbus. In one year alone, from 2001 to 2002, Boeing’s profits dropped 80 percent.

But the view from Seattle, the headquarters of Boeing’s commercial jet operations, has more of that Chinese pep-rally spirit than such gloomy talk might indicate . . . With revenue having grown for the second consecutive year, to \$54.8 billion in 2005, and a record number of orders on its books, Boeing has had a huge gain in its stock price—to more than \$80 a share, more than three times its nadir of \$25 in 2003. Boeing’s 1,002 orders last

Box 1.2
(continued)

year fell short of Airbus's 1,055. But Boeing's orders included more wide-body planes, which analysts valued at \$10 billion to \$15 billion more than Airbus's.

But what is really driving the high spirits at Boeing—and the high stock price—is a plane that has not yet taken to the skies: the 787. It is Boeing's first new commercial airplane in a decade. Even though it will not go into service until 2008, its first three years of production are already sold out—with 60 of the 345 planes on order going to China, a \$7.2 billion deal. Other big orders have come from Qantas Airways, All Nippon Airways, Japan Airlines, and Northwest Airlines.

Big orders mean big money, of course—and that is good, because analysts estimate that Boeing and its partners will invest \$8 billion to develop the 787. Boeing is also risking a new way of doing business and a new way of building airplanes: farming out production of most major components to other companies, many outside the United States, and using a carbon-fiber composite material in place of aluminum for about half of each plane.

If it works, Boeing could vault back in front of Airbus, perhaps decisively. If it fails, Boeing could be relegated to the status of a permanent also-ran, having badly miscalculated the future of commercial aviation and unable to meet the changing needs of its customers.

"The entire company is riding on the wings of the 787 Dreamliner," said Loren B. Thompson, an aviation expert at the Lexington Institute, a research and lobbying group in Arlington, Virginia, that focuses on the aerospace and military industries. "It's the most complicated plane ever."

Boeing calls the 787 Dreamliner a "game changer," with a radically different approach to aircraft design that it says will transform aviation. A lightweight one-piece carbon-fiber fuselage, for instance, replaces 1,200 sheets of aluminum and 40,000 rivets, and is about 15 percent lighter. The extensive use of composites, already used to a lesser extent in many other jets, helps improve fuel efficiency.

To convince potential customers of the benefits of composite—similar to the material used to make golf clubs and tennis rackets—Boeing gives them hammers to bang against an aluminum panel, which dents, and against a composite one, which does not. At the same time, the 787 has new engines with bigger fans that are expected to let the plane sip 20 percent less fuel per mile than similarly sized twin-engine planes, like Boeing's own 767 and many from Airbus. This is no small sales point, with oil fetching around \$70 a barrel and many airlines struggling to make a profit even as they pack more passengers into their planes.

"The 787 is the most successful new launch of a plane—ever," said Howard A. Rubel, an aerospace analyst at Jeffries & Company, an investment bank that has advised a Boeing subsidiary . . . The 787 is designed to carry 220 to 300 people on routes from North America to Europe and Asia. Boeing is counting on it to replace the workhorse 767, which is being

Box 1.2
(continued)

phased out, and, it hopes, a few Airbus models as well. Its advantages go beyond fuel efficiency: Boeing designed the 787 to fly long distances while keeping passengers relatively comfortable.

That approach grows out of another gamble by Boeing—that the future of the airline business will be in point-to-point nonstop flights with medium-size planes rather than the current hub-and-spoke model favored by Airbus, which is developing the 550-seat A380 superjumbo as its premier long-haul jetliner. Flying point to point eliminates the need for most passengers to change planes, a competitive advantage so long as the Dreamliner is as comfortable and as fast as a bigger aircraft.

And after talking with passengers around the world, Boeing designed the 787 to have higher humidity and more headroom than other airplanes, and to provide the largest windows of any commercial plane flying today.

“We are trying to reconnect passengers to the flying experience,” said Kenneth G. Price, a Boeing fleet revenue analyst. With airlines squeezing every last cent and cutting back service, “flying is not enjoyable,” Mr. Price said. “Every culture fantasizes about flying,” he added. “All superheroes fly. But we were taking a magical experience and beating the magic out.”

Even more innovative for Boeing is the way it makes the 787. Most of the design and construction, along with up to 40 percent of the estimated \$8 billion in development costs, is being outsourced to subcontractors in six other countries and hundreds of suppliers around the world. Mitsubishi of Japan, for example, is making the wings, a particularly complex task that Boeing always reserved for itself. Messier-Dowty of France is making the landing gear and Latecoere the doors. Alenia Aeronautica of Italy was given parts of the fuselage and tail.

Nor are these foreign suppliers simply building to Boeing specifications. Instead, they are being given the freedom, and the responsibility, to design the components and to raise billions of dollars in development costs that are usually shouldered by Boeing.

This transformation did not come overnight, of course, nor did it begin spontaneously. Boeing changed because it had to, analysts said. “Starting in 2000, Airbus was doing well,” said Richard L. Aboulafia, an aerospace analyst with the Teal Group, an aviation research firm in Fairfax, Va. “Boeing had to reconsider how it did business. That led to the framework for the 787—getting the development risk off the books of Boeing and coming up with a killer application.”

Boeing plans to bring the 787 to market in four and a half years, which is 16 to 18 months faster than most other models. All of that is good, Mr. Aboulafia added, if it works. It is a tall order for a wholly new plane being built with new materials, many from new suppliers and assembled in a new way. “The 787 is operating on an aggressive timetable and with aggressive performance goals,” he said. “It leaves no margin for error.”

Box 1.2
(continued)

Never before has Boeing farmed out so much work to so many partners—and in so many countries. The outsourcing is so extensive that Boeing acknowledges it has no idea how many people around the world are working on the 787 project.

Airbus, Boeing's sole rival in making big commercial airliners, is also making a big bet on the future, but in a different direction. The companies agree that in 20 years, the commercial aviation market may double, with today's big orders from China, India, and the Middle East to be followed by increased sales to American and European carriers as they reorganize and reduce costs.

By 2024, Boeing estimates, 35,000 commercial planes will be flying, more than twice the number now aloft, and 26,000 new planes will be needed to satisfy additional demand and replace aging ones. But how passengers will get from place to place, and in what planes, will depend on whether Boeing or Airbus has correctly forecast the future.

Boeing believes that passengers will want more frequent nonstop flights between major destinations—what the industry calls “city pairs.” That is what led to the big bet on the Dreamliner, a midsize wide-body plane that can fly nonstop between almost any two global cities—say, Boston to Athens, or Seattle to Osaka—and go such long distances at a lower cost than other aircraft.

Airbus believes that airplane size is more important than frequent nonstop flights and that passengers will stick with a hub-and-spoke system in which a passenger in, say, Seattle, will fly to Los Angeles and transfer to an Airbus 380 to go to Tokyo before catching a smaller plane to Osaka. That view has led it to spend \$12 billion to develop the double-deck A380, the largest passenger jet ever—a bet that is as crucial to its future as the 787 is to Boeing's.

“We have a fundamental difference with Airbus on how airlines will accommodate growth,” said Randolph S. Baseler, Boeing's vice president for marketing. “They are predicting flat growth in city pairs. We are saying that people want more frequent nonstop flights. They believe airplane size will increase, and we believe that airplanes will not increase in size that much. Those two different market scenarios lead to two different product strategies.”

The market, of course, will determine the winner, but given the industry's long lead times, that may not be clear for 10 to 20 years. For now, airlines have ordered 159 copies of the A380—which has a list price of \$295 million and is scheduled to enter service this year—and more than twice as many 787s, which list for \$130 million and are scheduled to enter service in two years.

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have faced over the recent years, focusing on the changes in corporate strategy of Boeing compared with Airbus. A manager from Boeing discusses in box 1.3 the use of real options to capture and assess the diverse sources of uncertainty in his business; an analysis of the strategic interplay vis-à-vis Airbus is highlighted.

1.2 What Is Strategy?

Corporate strategy is high on the agenda of every major corporation.² The strategy a firm formulates and how it implements that strategy will determine to a large extent whether it will survive and be successful in the marketplace or become extinct. Formulating the right strategy in the right place at the right time is not an easy task. It requires deep analysis and ready-to-implement, adaptable solution programs.

Our approach to strategy is based on the premise that strategic management is a structured, rational discipline relying on rigorous market and competitive analysis. One can understand why firms succeed or fail by analyzing their decision processes in terms of consistent principles of market economics and rational strategic actions. This is the reason why a large literature in strategic management relies on economic theory as it provides a reliable, rigorous foundation to understanding specific developments and reactions taking place in the market place.

Good firm performance is considered the result of soundly formulated and well-implemented strategies. Grant (2005) identifies the following elements as key to a successful strategy: (1) simple, agreed-upon, long-term objectives; (2) deep understanding of the competitive landscape; (3) objective appraisal of the firm's internal resources and capabilities; and (4) effective implementation. There are no easy "recipes for success" applicable to each firm in every industry.³ The pursuit of one-size-fits-all

2. Although it is commonly agreed that strategy is critical in today's changing corporate environment, there is no universally agreed-upon definition of business strategy. According to Chandler (1962), strategy is "the determination of the basic long-term goals and objectives of an enterprise and the adoption of courses of action and the allocation of resources necessary for carrying out these goals." According to Mintzberg et al. (2002), strategy is "the pattern or plan that integrates an organization's goals, policies and action sequences into a cohesive whole."

3. There are two main approaches to strategy formulation. The first approach looks at specific firms or case studies examining why these firms are successful and tries to deduce success factors that might be applicable to other firms. This is the "best-practices" approach. Herein we take a different approach. We formulate a conceptual framework for strategic management and assess if it provides prescriptive insights into real-world managerial problems.

Box 1.3
Interview with Scott Matthews, Boeing



1. Do you believe real options is more suitable than other capital budgeting approaches to provide managerial guidance? Where and to what extent is real options analysis used at Boeing?

Real options provides a more informed decision for our strategic projects. Of special significance are the scenarios that we build around the real options analyses that help us understand both the risks and the opportunities of any venture. To date, real options analysis has been used mostly on large-scale projects. Because of the higher investment amounts, these large projects pose particular risks that require more careful analyses including the use of real options techniques.

2. What are the sources of uncertainty you face at Boeing, and how do you manage them with options, physical or contractual?

Boeing projects have many sources of uncertainty. We build models that attempt to integrate technology development, design, manufacture, supply chain, and market forces, including possible actions of our competitors. These models have dozens, even hundreds, of variables modeled using various Monte Carlo and discrete event simulation capabilities. Usually there are just a handful of principal uncertainty drivers which are determined using sensitivity analysis. We then apply a series of targeted investments to investigate and better understand the true scale of these uncertainties. Since the uncertainty landscape is in constant evolution, due to both our risk mitigation efforts as well as exogenous events, we continue to update the model and modify our investments as appropriate. These are

Box 1.3

(continued)

often modeled as real option investments with a type of varying volatility, as we are attempting to both reduce uncertainty while at the same time increase the value of the subsequent project stage.

3. Do you see a usefulness for game theory and option games in Boeing's strategic thinking, for example, vis-à-vis Airbus?

We find that game-theoretical approaches provide additional insight to a solution set as long as the number of actors is limited to just a few players. At a certain point market considerations dominate and provide a better approach to modeling the scenarios. We have managed to execute a few plays against our competitors, the origin of which could be traced back to strategic gaming scenarios and market timing. When we are successful, these plays are often highly leveraged, and therefore take on the characteristics of well-placed option investments. However, like other companies in dynamic markets, we find our competitive response limited by timing or technology and product availability considerations.

success factors has failed to provide a coherent direction to guide the actions and decisions of firms.

Ghemawat (1991) criticizes the success factors approach and identifies commitment as a main driver of corporate success or failure. He sees commitment as a well-thought-out plan of action affecting the firm in the long term. A successful strategy should exhibit consistent but adaptive behavior over time and involve certain strategic commitments that might sometimes hinder managerial flexibility. This feature of strategy implies that, in an uncertain environment, resolving the investment or commitment timing issue is critical to a firm's success. A firm should not always invest or commit immediately, but should be prepared to decide at the right moment to reap the benefits of a developing opportunity. As suggested by Dixit and Pindyck (1994), investment situations where decisions are costly or impossible to reverse compel corporate managers to be cautious and careful to make decisions at the right time.

Strategy should also be dynamic in that it should be adaptable to changing market circumstances or competitive dynamics. Following Rumelt (1984, p. 569), the essence of competitive strategy is being in "constant search for ways in which the firm's unique resources can be redeployed in changing circumstances." The increasing cone of market and strategic (competitive) uncertainty makes the dynamic formulation of strategy key to survival and success in a changing marketplace. Box 1.4

Box 1.4
Flexible strategy and real options

Stay Loose: By Breaking Decisions into Stages, Executives Can Build Flexibility into Their Plans

Lenos Trigeorgis, Rainer Brosch, and Han Smit, *Wall Street Journal*

In turbulent times adaptability is critical. That's why today flexibility is more valuable than ever in business strategy. Markets, technologies, and competition are becoming more dynamic by the day. To succeed in this environment, companies need to position themselves to capitalize on opportunities as they emerge, while limiting the damage if adversity hits. This requires a whole new level of flexibility.

Good managers have always been able to think on their feet. But many widely applied tools of strategy development were designed for relatively stable environments. As a result business strategy may too often lock managers into decisions that turn out to be flawed because something outside their control doesn't go as planned. What is needed is a systematic translation of managers' flexibility into strategy—a plan that lays out a series of options for managers to pursue or decline as developments warrant.

That is the essence of what is known as “real options” analysis, an approach that borrows from the workings of the financial markets. Just as stock options, for instance, give the holder the right, but not the obligation, to buy or sell shares at a given price at some time in the future, real options give executives the right, but not the obligation, to pursue certain business initiatives.

Start Small

Instead of making rock-hard plans and irreversible long-term commitments, the idea is to create flexibility by breaking decisions down into stages. When building a new plant, for example, it may be tempting to realize the full economies of scale by building the biggest facility the company can manage. But it may be wiser to first build a smaller plant that can be easily expanded later on. That way, if the market for the products the plant produces should decline, a smaller investment has been put at risk. At that point managers have the option to scale down or abandon operations. On the other hand, if things turn out well, they have the option to expand the plant.

As a mind-set this approach encourages managers to be flexible in their planning. In more concrete terms it allows them to value investment decisions and business initiatives in a new way. Instead of making a decision based on a rigid financial analysis of a given project as a whole, managers can analyze, from the start, the financial implications of each step along the way and every potential variation—without committing to anything

Box 1.4
(continued)

before they must. Once the project is under way, they also can account for the changing value of each option as events unfold. All that information gives them a clearer framework for decisions on whether to launch a project and whether to proceed, hold back, or retreat at each stage.

What does this look like in practice? A leading European automaker was considering two investment alternatives for the production of a new vehicle. Under one alternative, production would be based entirely in one country. Under the other, the company would set up plants around the world, allowing it to switch production from site to site to take advantage of fluctuations in exchange rates or labor costs. The cost of the flexible system would be higher. But the company decided that the value of that flexibility, with its promise of cost savings and increased profits, exceeded the difference in cost between the two alternatives. So it chose the multinational plan.

Competitive Edge

Real options analysis can also be useful in helping strategic planners address the challenges of competition. Many managers already incorporate game theory into their planning to help predict how competition will play out. But with competition emerging and evolving more rapidly than ever, supplementing game theory with real options analysis can help companies be more flexible in how they react.

Consider, for example, the question of whether a company should aim to preempt competition or choose to cooperate with other players in a way that could expand the market. This is a question of growing relevance as sometimes competing technologies are at the heart of more products. In deciding whether to fight or cooperate, companies can use real options analysis to better quantify the value of each contingency, including the value of the options that would be lost or gained depending on what competitive course is chosen.

What this all adds up to is a portfolio of corporate real options, each with a value that will change along with the company's developing markets. Those who manage that portfolio most effectively will be in the best position to realize their company's growth potential.

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discusses the need for strategic plans to be flexible and adaptable in a changing environment. Since strategic decisions have long-term consequences, one should look not only at today's advantages or drawbacks but also at the long-term consequences and value of such decisions. The trade-off between the benefits of commitment (as part of a consistent strategy over time) and remaining flexible and adaptive to changing circumstances calls for an integrative approach weighing the merits of flexibility against commitment.

1.3 Two Complementary Perspectives on Strategy

Two approaches to strategy are of particular interest as they provide insights that help management deal with the flexibility or commitment trade-off: corporate finance and game theory. These disciplines are generally considered separate but are in fact complementary. We discuss each one next.

1.3.1 Corporate Finance and Strategy

At first sight the link between corporate finance and strategy may not be that clear. Within corporations, finance is in charge of raising firm resources, while the strategy department is concerned with how to allocate these resources strategically. The two departments deal, however, with two sides of the same coin. Financial managers are concerned with how to finance a project at a reasonable cost. They are aware that resource providers (e.g., shareholders or banks) will carefully scrutinize what the firm plans to do with the resources they are asked to provide, carefully assessing the firm's strategic plans and the quality of its management. The formed opinion of the resource providers will influence the cost of the resources the firm has access to. A good financial manager cannot therefore ignore the firm's strategy. Understanding and communicating the firm's strategy should be one of her primary tasks.

Following a finance theory approach, the objective of the firm is to maximize the wealth (utility) of shareholders. According to the Fisher separation theorem, this objective is achieved when maximizing the firm's market value. A fundamental question in corporate finance is how to attain this objective. As part of corporate finance, capital budgeting considers this problem from an investment perspective, being concerned with the optimal allocation of scarce resources among alternative

projects.⁴ A key issue is how to address the intertemporal trade-off faced by a firm between paying more dividends or cash distributions now and investing in growth projects meant to generate future cash flows.

The established criterion in capital budgeting is the discounted cash-flow (DCF) or net present value (NPV) method. The approach involves a relatively easy-to-understand logic and methodology that consists in assessing the current value of a project based on the *expected* future cash flows it will generate, net of the related costs. Management estimates the stream of future expected cash flows over the project's life and discounts them back to the present using a risk-adjusted discount rate, obtaining the project's present value V . It then subtracts the (present value of) investment outlays, I , obtaining the current ($t = 0$) *net present value*:⁵

$$NPV = V - I. \quad (1.1)$$

Alternatively, the present value represents the discounted sum of economic profits.⁶ The *economic profit* in a given period represents the firm's total revenue earned in that period minus all relevant opportunity costs, including the cost of capital. Following the DCF or NPV paradigm, the firm creates shareholder value by following the *NPV rule*, prescribing to immediately undertake projects with positive NPV, meaning $NPV > 0$ or $V > I$. In the absence of managerial flexibility, net present value is the main valuation measure consistent with the firm's objective to maximize shareholders' wealth.⁷ Other valuation measures, such as payback period, accounting rate of return, or internal rate of return are considered inferior to NPV and sometimes even inconsistent.

The above finance theory often appears rather technical and not so relevant for strategic management practice. Already in Myers (1984), a

4. Corporate finance provides a useful frame to help managers make investment and financing decisions. Two subfields of corporate finance are particularly relevant for corporate managers: *capital budgeting*, or how to make investment decisions, and *financing*, or how to finance projects at the lowest cost available. It is commonly agreed that *real* investments are more important for creating shareholder value than financial engineering.

5. Consider a project generating over its lifetime (T years) expected cash inflows $E[R_t]$ in each future year t . Launching the project is costly, involving expected cash outflows $E[C_t]$. Let $V \equiv \sum_{t=0}^T E[R_t]/(1+k)^t$ and $I \equiv \sum_{t=0}^T E[C_t]/(1+k)^t$ denote the present value of the stream of cash inflows and outflows, respectively. k denotes the appropriate risk-adjusted discount rate. The necessary cash outflow I might be a single investment outlay incurred at the outset or the present value of a series of outflows.

6. The economic value added (EVA) approach is based on this notion.

7. Throughout the book, we ignore agency problems inside a firm that may invalidate the NPV rule. Myers (1977) discusses the problem of "underinvestment." Managers acting in the shareholders' interest may reject projects with positive NPV when the firm is close to bankruptcy since investing in these projects would only benefit debt-holders.

gap between finance and strategy was identified. Myers offers three main explanations for this gap:

- ***NPV is often mistakenly applied*** Firms in practice often pursue financial objectives that are inconsistent with basic financial theory. They may focus on short-term results rather than long-term value creation. For instance, firms may worry about the impact of their strategic decisions on today's P&L and on today's balance sheet.⁸ Financial theory in fact stresses the importance of taking a long-term perspective to enhancing firm value over short-term creative accounting.⁹ The balance sheet or income statement are accounting instruments presenting snapshots of the moment or period and do not necessarily mirror real long-term value creation. Another pitfall is that some managers may pursue corporate diversification to reduce total risk for their own benefit.¹⁰ In addition managers often treat available divisional resources as being limited. This internally imposed constraint is in sharp contrast with the basic finance assumption that firms have ready access to capital markets at the prevailing cost of capital. Even if acquiring new financial resources may be more costly, the project should be adopted if the project brings more value than it costs to undertake it.

- ***Finance and strategy mind-sets differ*** They represent two cultures looking at the same problem. In perfect competition the firm presumably makes no excess economic profit. Strategists are thus looking for deviations from perfect competition to generate excess profits. Such deviations result from distinctive sustainable *competitive advantages*. Given the linkage between competitive advantage and excess economic profits, strategists often find it superfluous to determine the net present value (as the discounted sum of economic profits) once they have identified the source of competitive advantages.

- ***NPV has limited applicability*** The DCF approach involves the estimation of a risk-adjusted discount rate, a forecast of expected cash flows, and an assessment of potential side effects (e.g., erosion or synergies between projects) or time-series links between projects. The last aspect is most difficult to handle with traditional techniques because

8. Other common mistakes include the inconsistent treatment of inflation (deflated cash flows discounted back at a discount rate assuming inflation) and unrealistic hurdle rates (use of discount rates that take into account both systematic and diversifiable risk).

9. Short-term orientation is allegedly rampant in countries relying heavily on the capital markets.

10. Risk reduction through portfolio diversification had better be undertaken by investors directly in the capital markets; corporate diversification undertaken by managers is a less efficient means to diversify risk.

today's investment decisions may constrain or open up new future opportunities.

NPV has other drawbacks. First, the NPV paradigm views investment opportunities as now-or-never decisions under *passive management*. This precludes the possibility to adjust future decisions to unexpected future developments in industry cycles, demand, or prices. Firms need to position themselves to capitalize on opportunities as they emerge while limiting the damage arising from adverse circumstances. If market developments deviate significantly from the expected future scenario, managers can generally revise their future decisions to protect themselves from adverse downward movements or tap on favorable developments and further growth potential. Applying the NPV rule strictly is ill-advised when managers can adjust their planned investment programs or delay and stage their investment decisions. Managers following the prescriptions offered by NPV may find themselves locked into decisions that are flawed when something outside their control does not go as planned. Second, NPV typically assumes a constant discount rate for each future time and state scenario regardless of whether the situation is favorable. Table 1.1 summarizes situations where NPV might give a good approximation of reality and when it might be misleading. Finally, NPV typically overlooks the consequences of competitive actions.

Strategy is in need of a quantitative tool that allows for dynamic consideration of changing circumstances. Academics have attempted early on to use alternative approaches to overcome the problems inherent in NPV, particularly to deal with uncertainty and the dynamic nature of investment decision-making. Such methods include sensitivity analysis,

Table 1.1
Use of NPV for financial and corporate real assets

	Financial assets	Corporate real assets
Appropriate	Valuation of bonds, preferred stocks, and fixed-income securities Valuation of relatively safe stocks paying regular dividends	Valuation of flows from financial leases Valuation of "cash cows"
Inappropriate	Valuation of companies with significant growth opportunities Valuation of call and put options	Valuation of projects with substantial growth opportunities Valuation of R&D projects

Source: Myers (1984, p. 135).

simulation, and decision-tree analysis. Each has had, however, known drawbacks. *Sensitivity analysis* considers each variable in isolation, thereby ignoring correlations among them. *Simulation* (e.g., Monte Carlo) faces the same risk-adjustment (discount rate) problem as NPV and generally requires additional adjustment to handle certain recursive problems (e.g., American options) because it is a forward-looking process. Sensitivity analysis and standard simulation are *static* approaches in that they assume that management is precommitted to a previously agreed-upon course of action. In real life this hardly holds. Managers have valuable flexibility and can adapt to the actual market developments once uncertainty gets resolved. They may, for example, abandon a once-undertaken project if the prospects prove gloomy. Managers may also have other options to alter project features in view of the actual market development.

Decision-tree analysis (DTA) can be seen as a refined version of NPV aimed to take into consideration the *dynamic* nature and across-time linkages of decision-making. DTA attributes probabilities to different states of the world and determines in each case the strategy management should optimally formulate (e.g., increase the production scale, switch off the plant, exit the market). In this respect DTA considers the options management has and provides better insights on the dynamic structure of the problem. Trigeorgis and Mason (1987) point out that DTA fails, however, to be economically sound. The discount rate might not be constant over time or across states as typically assumed. Determining the real probabilities of occurrence of each state is often quite involved. *Real options analysis* (ROA) is an enhanced version of decision-tree analysis that provides improvement in terms of risk-adjustment and determination of probabilities.¹¹ This enhancement is the result of using insights from option-pricing theory.¹² Just as stock options give the holder the right, but not the obligation, to buy or sell shares at a given price at some time in the future, real options gives executives the right, but not the obligation, to pursue certain business initiatives. ROA is operationally similar to DTA, with the key difference that the probabilities are risk-adjusted, which allows the use of the risk-free discount rate. Real options

11. Several corporate-finance textbooks subsume DTA into real options analysis. We disagree. Real options is the application of option-pricing theory (contingent claims analysis) and risk-neutral pricing to real investment situations (Myers 1977).

12. An alternative to NPV for risk-adjusting risky future cash flows is to consider the certainty equivalents of the uncertain future cash flows and discount them at the risk-free rate. This alternative approach for risk adjustment is a cornerstone of risk-neutral pricing and real options analysis.

analysis is an innovative capital-budgeting tool suitable for the analysis of dynamic decision making under exogenous uncertainty. It enables quantifying strategic considerations that justify sometimes undertaking projects with negative (static) net present value or delaying projects with positive NPV. Box 1.5 highlights the challenges managers face under uncertainty, the inability of NPV to cope with them, and the usefulness of real options in practice.

1.3.2 Game Theory and Strategy

Corporate life would be rather comfortable if a single firm were the only one operating in the marketplace. As a monopolist the firm could

Box 1.5
Uncertainty, NPV, and real options in practice

Getting Real: Want to Take More Uncertainty out of Capital Investment Decisions? Try Real Options

S. L. Mintz, *CFO Magazine*

“The Edsel is here to stay.” That’s what Ford Motor Co. chairman Henry Ford II told Ford dealers in 1957. “There is no reason why anyone would want a computer in their home.” Thus intoned Digital Equipment Corp. founder Kenneth Olsen in 1977. Even for business leaders with vision, the future is difficult to predict. So where does that leave less-than-legendary executives come budget-planning season? Stuck, largely, with the same venerable tools that guided their predecessors and their predecessors: net present value and gut instinct.

Short of denigrating tools that account for many great successes (along with memorable flubs), many executives are wondering if that’s all there is. “There is definitely room for improvement,” concedes Rens Buchwaldt, CFO of Bell & Howell Publishing Services, in Cleveland. Large capital-investment decisions—whether it’s launching a new automobile, or building a chip-fabrication plant, or installing an ERP system, or making any number of other very pricey investments—hurl companies toward uncertain outcomes. Huge sums are at risk, in a competitive climate that demands ever-faster decisions. Is there a better way to evaluate capital investments? A growing and vocal cadre of academics, consultants, and CFOs say there is one: real options.

Fans insist that real options analysis extends quantitative rigor beyond discount rates and expected cash flows. “Everybody knew there was some kind of embedded value” in strategic options, says an oil industry finance

Box 1.5
(continued)

executive. Real options analysis, he says, brings that embedded value to light.

By quantifying the fuzzy realm of strategic judgment, where leaps of faith govern decisions, real options analysis fosters the union of finance and strategy. “It’s a way to be a little more precise about intuitive feelings,” says Tom Unterman, CFO of \$3 billion Times Mirror Co., the Los Angeles based news and information company. A real options analysis recently bolstered the company’s decision to back away from an acquisition, says Unterman, and wider use of the approach is foreseeable. “We are quite actively looking for ways to apply it,” he says.

Casting investment opportunities as real options increased both the top and bottom lines at Cadence Design Systems Inc., a San Jose, California, based provider of electronic design products and services. “We have closed a number of transactions that we would not have closed before,” CEO Ray Bingham declares . . .

The Value of Flexibility

Unlike net present value measurements, real options analysis recognizes the flexibility inherent in most capital projects—and the value of that flexibility. To executives familiar with stock options, real options should look familiar. A stock option captures the value of an investor’s opportunity to purchase stock at a later date at a set price. Similarly a real option captures the value of a company’s opportunity to start, expand, constrain, defer, or scrap a capital investment depending on the investment’s prospects. When the outcome of an investment is least certain, real options analysis has the highest value. As time goes by and prospects for an underlying investment become clearer, the value of an option adjusts.

Sweep away the rocket science, and real options analysis presents a more realistic view of an uncertain world beset by constant shifts in prices, interest rates, consumer tastes, and technology. To focus strictly on numerical value misses the depth and complexity of real options discipline, observes Nalin Kulatilaka, a professor of finance at Boston University School of Management. Kulatilaka is an evangelist for a methodology that obliges managers to weigh equally all imaginable alternatives, good and bad.

Real options analysis liberates managers from notions of accountability that mete out blame when plans don’t go as expected. That’s not a healthy environment for workers or companies that need to be nimble all the time, if not right all the time. “The best decision may lead to a bad outcome,” says Soussan Faiz, manager of global valuation services at oil giant Texaco Inc. “If you are judged on a bad outcome, guess what? People will say,

Box 1.5
(continued)

“Why go through that?” To succeed today, companies must create new options. But unless managers are rewarded for creating them, Faiz warns, “it ain’t gonna happen.”

Certainty Is a Narrow Path

By taking uncertainty into account, real options analysis fosters a more dynamic view of the world than net present value does. Net present value ultimately boils down to one of two decisions: go or no-go. When the net present value of expected cash flows is positive, companies usually proceed. As a practical consequence managers concentrate on prospects for favorable outcomes. Prospects for unfavorable outcomes get short shrift. In this analysis certainty enjoys a premium—and that’s a narrow path. Even without gaming the numbers to justify projects, this upside bias invites unpleasant surprises.

“Unfortunately, discounted cash flow collapses to a single path,” says Texaco’s Faiz. Management and measurement are intertwined, she explains, yet companies manage with an eye to options, but measure performance as if options don’t exist. In the oil business, oil prices don’t remain low for the life of a project; they bounce back. “The likelihood of prices being low for the rest of the project is zero or nearly zero,” says Faiz. But even if prices do remain stagnant, defying the odds, managers don’t snooze the whole time. They wake up and react. Net present value, however, treats investments as if outcomes are cast in stone. This, needless to say, is not realistic. “Net present value makes a lot of heroic assumptions,” warns Tom Copeland, chief corporate finance officer of Monitor, a strategy consultancy in Cambridge, Massachusetts. Typically a multiyear project is plotted along a single trajectory worth pursuing only if the net present value exceeds zero or some hurdle rate. This type of reasoning may satisfy requirements for a midterm exam, says Copeland, but situations in the real world change constantly as new information surfaces. Most managers realize that flexibility ought to be included in valuations, Copeland says. “The bridge they have to cross is understanding the methodology to capture the value of flexibility.”

Out of the Ivory Tower

Experts have touted the merits of real options for at least a decade, but the sophisticated mathematics required to explain them has penned up those merits in ivory towers. That’s changing, as proponents tout the virtues of real options as a mind-set for decision-making . . .

“The kinds of businesses companies go into today are difficult to go into with NPV,” says John Vaughan, vice president for business development

Box 1.5
(continued)

at M/A-COM, the Lowell, Massachusetts, based wireless products group of AMP Inc . . . Net present value would have derailed this project long ago, Vaughan insists. “It would have been difficult to sell this business case, because of the high level of uncertainty,” he says. Real options analysis assembles diverse risks in a coherent fashion, Vaughan says, layer upon layer, like a papier-mâché creation. “It very much mimics the venture capitalist approach,” he says, “by timing expenditures to the maturity of the opportunity.”

Handle with Care

Real options “add richness and perspective I can’t get elsewhere,” says the oil industry executive. But like any metric that relies on judgment, he warns, real options must be used carefully. They are not tamper-proof. “Given enough volatility and time,” he says, “I can make an option a very big number.” Without solid, accurate measures of volatility, real options can lead companies astray. For evaluating an offshore oil lease, look at the history of oil-futures prices; for a petrochemical plant, look at historical futures and options contracts on margins . . .

“I don’t think the value of great judgment or intuition is any less in using a more sophisticated model,” Bingham says. To the extent that real options analysis sheds more light on uncertainty, in his view, it provides a critical link between strategy and finance. Says Bingham: “Getting hold of real options will make a CFO more and more relevant and a valuable part of leadership.”

In an uncertain world, that’s the sort of vision CFOs rely on.

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sometimes make wrong decisions with limited adverse consequences. In contrast, when several firms are active in the market, managers are under constant competitive pressure to make the right decisions all the time. Otherwise, the firm might go belly-up. In perfect competition the decisions of a single firm do not have a significant impact on others, and strategic interactions are again inconsequential. In reality, however, industries are rarely either purely monopolistic or perfectly competitive. In the real marketplace that is closer to oligopoly, firms typically respond to their rivals’ actions. This calls for an appropriate methodology, namely game theory.

Over the last half century game theory has developed into a rigorous framework for assessing strategic alternatives.¹³ It helps managers formulate the right strategies and make the right decisions under competition. A recent article in CFO magazine epitomizes a renewed interest by companies in using game theory to aid decision-making (see box 1.6). The origins of game theory trace back to the 1900s when mathematicians got interested in studying various interactive games, such as chess and poker. The first comprehensive formulation of the concept of optimal

Box 1.6
Game theory in business practice

More Companies Are Using Game Theory to Aid Decision-Making: How Well Does It Work in the Real World?

Alan Rappeport, *CFO Magazine*

When Microsoft announced its intention to acquire Yahoo last February, the software giant knew the struggling search firm would not come easily into the fold. But Microsoft had anticipated the eventual minuet of offer and counteroffer five months before its announcement, thanks to the powers of game theory.

A mathematical method of analyzing game-playing strategies, game theory is catching on with corporate planners, enabling them to test their moves against the possible responses of their competitors. Its origins trace as far back as *The Art of War*, the unlikely management best seller penned 2,500 years ago by the Chinese general Sun Tzu. Mathematicians John von Neumann and Oskar Morgenstern adapted the method for economics in the 1940s, and game theory entered the academic mainstream in the 1970s, when economists like Thomas Schelling and Robert Aumann used it to study adverse selection and problems of asymmetric information. (Schelling and Aumann won Nobel Prizes in 2005 for their work.)

Game theory can take many forms, but most companies use a simplified version that focuses executives on the mind-set of the competition. “The formal stuff quickly becomes very technical and less useful,” says Louis Thomas, a professor at the Wharton School of Business who teaches game theory. “It’s a matter of peeling it back to its bare essentials.” One popular way to teach the theory hinges on a situation called the “prisoner’s

13. Game theory is concerned with the actions of decision makers conscious that their actions affect those of rivals and that the actions of competitors, in turn, impact their own decisions. When many players can disregard strategic interactions as being inconsequential (*perfect competition*) or when a firm can reasonably ignore other parties’ actions (*monopoly*), standard optimization techniques suffice. Under imperfect competition such as in *oligopoly*, a limited number of firms with conflicting interests interact such that the actions of each can materially influence firm individual profits and values.

Box 1.6
(continued)

dilemma,” where the fate of two detainees depends on whether each snitches or stays silent about an alleged crime.

Many companies are reluctant to talk about the specifics of how they use game theory, or even to admit whether they use it at all. But oil giant Chevron makes no bones about it. “Game theory is our secret strategic weapon,” says Frank Koch, a Chevron decision analyst. Koch has publicly discussed Chevron’s use of game theory to predict how foreign governments and competitors will react when the company embarks on international projects. “It reveals the win-win and gives you the ability to more easily play out where things might lead,” he says.

Enter the Matrix

Microsoft’s interest in game theory was piqued by the disclosure that IBM was using the method to better understand the motivations of its competitors—including Microsoft—when Linux, the open-source computer operating system, began to catch on. (Consultants note that companies often bone up on game theory when they find out that competitors are already using it.)

For its Yahoo bid, Microsoft hired Open Options, a consultancy, to model the merger and plot a possible course for the transaction. Yahoo’s trepidation became clear from the outset. “We knew that they would not be particularly interested in the acquisition,” says Ken Headrick, product and marketing director of Microsoft’s Canadian online division, MSN. And indeed they weren’t; the bid ultimately failed and a subsequent partial acquisition offer was abandoned in June.

Open Options wouldn’t disclose specifics of its work for Microsoft, but in client workshops it asks attendees to answer detailed questions about their goals for a project—for example, “Should we enter this market?” “Will we need to eat costs to establish market share?” “Will a price war ensue?” Then assumptions about the motives of other players, such as competitors and government regulators, are ranked and different scenarios developed. The goals of all players are given numerical values and charted on a matrix. The exercise is intended to show that there are more outcomes to a situation than most minds can comprehend, and to get managers thinking about competition and customers differently.

“If you have four or five players, with four actions each might or might not take, that could lead to a million outcomes,” comments Tom Mitchell, CEO of Open Options. “And that’s a simple situation.” To simplify complex playing fields, Open Options uses algorithms to model what action a company should take—considering the likely actions of others—to attain its goals. The result replicates the so-called Nash

Box 1.6
(continued)

equilibrium, first proposed by John Forbes Nash, the Nobel Prize winning mathematician portrayed in the movie *A Beautiful Mind*. In this optimal state, the theory goes, a player no longer has an incentive to change his position.

As a tool, game theory can be useful in many areas of finance, particularly when decisions require both economic and strategic considerations. “CFOs welcome this because it takes into account financial inputs and blends them with nonfinancial inputs,” says Mitchell.

Rational to a Fault?

Some experts, however, question game theory’s usefulness in the real world. They say the theory is at odds with human nature because it assumes that all participants in a game will behave rationally. But as research in behavioral finance and economics has shown, common psychological biases can easily produce irrational decisions.

Similarly John Horn, a consultant at McKinsey, argues that game theory gives people too much credit. “Game theory assumes rationally maximizing competitors who understand everything that you’re doing and what they can do,” says Horn. “That’s not how people actually behave.” (Activist investor Carl Icahn said Yahoo’s board “acted irrationally” in rejecting Microsoft’s bid.) McKinsey’s latest survey on competitive behavior found that companies tend to neglect upcoming moves by competitors, relying passively on sources such as the news and annual reports. And when they learn of new threats, they tend to react in the most obvious way, focusing on near-term metrics such as earnings and market share.

Moreover finance executives have their own sets of metrics, and when favored indicators such as net present value clash with game theory models, choices become more complicated. “Sometimes [game theory] tells you things you don’t like,” says Koch.

Game theory is still finding its place as a tool for companies, and its ultimate usefulness may depend on how quickly it moves from novelty to accepted practice. Practice in fact may be key. McKinsey takes that to heart with its “war game” scenarios, in which a company’s top managers play the roles of different parties in a simulation. In effect this boils game theory down to the schoolyard lesson that perfection comes through repetition. “Discipline is not a dirty word,” as basketball coach Pat Riley once said. Game theory is one way that companies can assess their options with more discipline.

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strategies in a multiple-player setup came with *The Theory of Games and Economic Behavior* by John von Neumann and Oskar Morgenstern (1944). More critical advancements were made in the early 1950s when John F. Nash Jr. provided a broad mathematical basis for the study of equilibria in strategic conflict situations (Nash 1950a, b, 1951).¹⁴ More recently game theory has been applied in many fields, including political science, international relations, military strategy, law, sociology, psychology, and biology. Game theory has revolutionized microeconomics and given a strong analytical basis for studying real market structures. As firm competitiveness involves interactions among many players (firms, suppliers, buyers, etc.), it also brought appealing insights into strategic management. Box 1.7 provides an overview of the basics of game theory by Avinash Dixit. An interview with Professor Dixit concerning the interconnection between real options and game theory and his pedagogical approach is given in box 1.8.

To perform strategic analysis, one needs to reduce a complex multi-player problem into a simpler analytical structure that captures the essence of the conflict situation. As discussed later, conducting such an analysis involves a clear depiction of the “rules of the game,” namely (1) identifying the players, (2) describing their available alternative choices, (3) specifying the information structure of the game, (4) determining the payoff values attached to each possible strategy choice, and (5) specifying the order or sequence of the play.¹⁵ From a specified game structure, one may derive useful predictions on how rivals are likely to react (equilibrium strategies) in a given environment.

A key question commonly arises: how should managers view these models? Should they interpret them in a literal or in a metaphorical sense? There is no clear-cut answer, but the metaphorical interpretation is generally accepted as more appropriate. One of the underlying premises of standard game theory is the presumed rationality of economic agents.¹⁶ This assumption is not always consistent with real-world behavioral phenomena, so excessive mathematical rigor may limit the

14. Before John F. Nash's work, the focus of game theory was mostly on zero-sum games. Nash's (1950b) equilibrium concept applies to a large set of problems beyond zero-sum games. Myerson (1999) provides a comprehensive analysis of how the Nash equilibrium concept shaped economic theory.

15. The order of play may affect both the possible actions players can select from and the information they possess at the time they make their decisions.

16. Defining rationality and optimality in a given strategic setting is one of the core objectives of game theory. This has an impact on the choice of the game-theoretic solution concept. Nash equilibrium makes behavioral assumptions beyond common knowledge of rationality.

Box 1.7**Overview of game theory basics**

Avinash K. Dixit,
John J. K. Sherrerd '52 University Professor of Economics, Princeton
University

Game theory studies interactive decision-making, where the outcome for each participant or “player” depends on the actions of all. If you are a player in such a game, when choosing your course of action or “strategy” you must take into account the choices of others. But in thinking about their choices, you must recognize that they are thinking about yours, and in turn trying to take into account your thinking about their thinking, and so on.

It would seem that such thinking about thinking must be so complex and subtle that its successful practice must remain an arcane art. Indeed some aspects such as figuring out the true motives of rivals and recognizing complex patterns do often resist logical analysis. But many aspects of strategy can be studied and systematized into a science—game theory.

The Nash Equilibrium

The theory constructs a notion of “equilibrium” to which the complex chain of thinking about thinking could converge. Then the strategies of all players would be mutually consistent in the sense that each would be choosing his or her best response to the choices of the others. For such a theory to be useful, the equilibrium it posits should exist. Nash used novel mathematical techniques to prove the existence of equilibrium in a very general class of games. This paved the way for applications. Biologists have even used the notion of Nash equilibrium to formulate the idea of evolutionary stability. Here are a few examples to convey some ideas of game theory and the breadth of its scope.

The Prisoner’s Dilemma

In Joseph Heller’s novel *Catch-22*, allied victory in World War II is a forgone conclusion, and Yossarian does not want to be among the last ones to die. His commanding officer points out, “But suppose everyone on our side felt that way?” Yossarian replies, “Then I’d certainly be a damned fool to feel any other way, wouldn’t I?”

Every general reader has heard of the prisoner’s dilemma. The police interrogate two suspects separately, and suggest to each that he or she should fink on the other and turn state’s evidence. “If the other does not fink, then you can cut a good deal for yourself by giving evidence against the other: if the other finks and you hold out, the court will treat you especially harshly. Thus no matter what the other does, it is better for you to fink than not to fink—finking is your uniformly best or ‘dominant’ strategy.” This is the case whether the two are actually guilty, as in some

Box 1.7
(continued)

episodes of *NYPD Blue*, or innocent, as in the film *L.A. Confidential*. Of course, when both fink, they both fare worse than they would have if both had held out; but that outcome, though jointly desirable for them, collapses in the face of their separate temptations to fink.

Yossarian's dilemma is just a multi-person version of this. His death is not going to make any significant difference to the prospects of victory, and he is personally better off alive than dead. So avoiding death is his dominant strategy.

John Nash played an important role in interpreting the first experimental study of the prisoner's dilemma, which was conducted at the Rand Corporation in 1950.

Real-World Dilemmas

Once you recognize the general idea, you will see such dilemmas everywhere. Competing stores who undercut each other's prices when both would have done better if both had kept their prices high are victims of the dilemma. (But in this instance consumers benefit from the lower prices when sellers fink on each other.) The same concept explains why it is difficult to raise voluntary contributions, or to get people to volunteer enough time for worthwhile public causes.

How might such dilemmas be resolved? If the relationship of the player is repeated over a long time horizon, then the prospect of future cooperation may keep them from finking; this is the well-known tit-for-tat strategy. A "large" player who suffers disproportionately more from complete finking may act cooperatively even when the small is finking. Thus Saudi Arabia acts as a swing producer in OPEC, cutting its output to keep prices high when others produce more, and the United States bears a disproportionate share of the costs of its military alliances. Finally, if the group as a whole will do better in its external relations if it enjoys internal cooperation, then the process of biological or social selection may generate instincts or social norms that support cooperation and punish cheating. The innate sense of fairness and justice that is observed among human subjects in many laboratory experiments on game theory may have such an origin.

Mixing Moves

In football, when an offense faces a third down with a yard to go, a run up the middle is the usual or "percentage" play. But an occasional long pass in such a situation is important to keep the defense honest. Similarly a penalty kicker in soccer who kicks exclusively to the goalie's right, or a server in tennis who goes exclusively to the receiver's forehand, will fare poorly because the opponent will anticipate and counter the action. In such situations it is essential to mix one's moves randomly so that on any one occasion the action is unpredictable.

Box 1.7

(continued)

Mixing is most important in games where the players' interests are strictly opposed, and this happens most frequently in sports. Indeed recent empirical studies of serving in tennis grand slam finals, and penalty kicks in European soccer leagues, have found the behavior consistent with the theory.

Commitments

Greater freedom of action seems obviously desirable. But in games of bargaining, that need not be true because freedom to act can simply become freedom to concede to the other's demands. Committing yourself to a firm final offer leaves the other party the last chance to avoid a mutually disastrous breakdown, and this can get you a better deal. But a mere verbal declaration of firmness may not be credible. Devising actions to make one's commitment credible is one of the finer acts in the realm of strategic games. Members of a labor union send their leaders into wage-bargaining with firm instructions or mandates that tie their hands, thereby making it credible that they will not accept a lower offer. The executive branch of the US government engaged in international negotiations on trade or related matters can credibly take a firm stance by pointing out that the Congress would not ratify anything less. And a child is more likely to get the sweet or toy it wants if it is crying too loudly to hear your reasoned explanations of why it should not have it.

Thomas Schelling pioneered the study of credible commitments, and other more complex "strategic moves" like threats and promises. This has found many applications in diplomacy and war, which, as military strategist Karl von Clausewitz told us long ago, are two sides of the same strategic coin.

Information and Incentives

Suppose that you have just graduated with a major in computer science and have an idea for a totally new "killer app" that will integrate PCs, call phones, and TV sets to create a new medium. The profit potential is immense. You go to venture capitalists for finance to develop and market your idea. How do they know that the potential is as high as you claim it to be? The idea is too new for them to judge it independently. You have no track record, and you might be a complete charlatan who will use the money to live high for a few years and then disappear. One way for them to test your own belief in your idea is to see how much of your own money you are willing to risk in the project. Anyone can talk a good game; if you are willing to put enough of your money where your mouth is, that is a credible signal of your own true valuation of your idea.

This is a game where the players have different information; you know the true potential of your idea much better than does your prospective

Box 1.7
(continued)

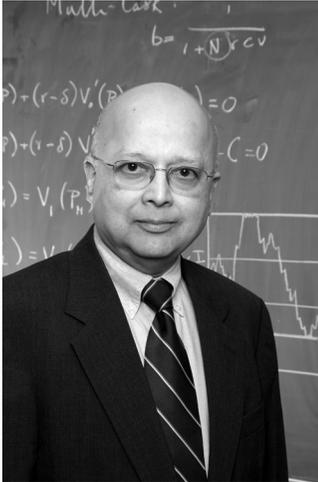
financier. In such games, actions that reveal or conceal information play crucial roles. The field of “information economics” has clarified many previously puzzling features of corporate governance and industrial organization, and has proved equally useful in political science, studies of contract and tort law, and even biology. The award of the Nobel Memorial Prize in 2001 to its pioneers, George Akerlof, Michael Spence, and Joseph Stiglitz, testifies to its importance. What has enabled information economics to burgeon in the last twenty years is the parallel development of concepts and techniques in game theory.

Aligning Interests, Avoiding Enrons

A related application in business economics is the design of incentive schemes. Modern corporations are owned by numerous shareholders who do not personally supervise the operations of the companies. How can they make sure that the workers and managers will make the appropriate efforts to maximize shareholder value? They can hire supervisors to watch over workers, and managers to watch over supervisors. But all such monitoring is imperfect: the time on the job is easily monitored, but the quality of effort is very difficult to observe and judge. And there remains the problem of who will watch over the upper-level management. Hence the importance of compensation schemes that align the interests of the workers and managers with those of the shareholders. Game theory and information economics have given us valuable insights into these issues. Of course, we do not have perfect solutions; for example, we are just discovering how top management can manipulate and distort the performance measures to increase their own compensation while hurting shareholders and workers alike. This is a game where shareholders and the government need to find and use better counterstrategies.

From Intuition to Prediction

While reading these examples, you probably thought that many of the lessons of game theory are obvious. If you have had some experience of playing similar games, you have probably intuited good strategies for them. What game theory does is to unify and systemize such intuitions. Then the general principles extend the intuitions across many related situations, and the calculation of good strategies for new games is simplified. It is no bad thing if an idea seems obvious when it is properly formulated and explained; on the contrary, a science or theory that takes simple ideas and brings out their full power and scope is all the more valuable for that.

Box 1.8**Interview with Avinash K. Dixit**

1. You have helped establish and popularize both real options and game theory as separate disciplines. How do you see the interconnection or interplay among the two?

The real options concept emphasizes the value of flexibility, whereas an irreversible commitment has value in many situations of strategic competition. Analyzing the two together enables us to understand when one prevails over the other, or more generally, the trade-off between the two. This is clearly an important research program.

2. In your teaching of game theory at Princeton you rely a lot on stories, movies, literature, sports, games, and other engaging tools to motivate your students. Can you elaborate on your view or approach?

Undergraduate students are rightly skeptical of abstract theory, and demand evidence of its relevance before they will spend their time and effort on studying theory. Game theory is fortunate in having so many compelling and entertaining examples readily available. Using examples to bring out theoretical concepts is similar to the case method used in most business schools. But MBA students are narrowly focused on business and moneymaking. Undergraduates have richer and more varied lives; therefore examples from sports, games, literature, and movies appeal to them.

3. What other current or future areas of research in economic sciences do you find interesting?

Connections between economics and other social sciences are enriching them all. Economists are becoming aware of aspects of human behavior

Box 1.8

(continued)

that differ from selfish rationality assumed in most traditional economic theory; sociologists, political scientists, and even psychologists and anthropologists are learning the value of economists' conceptual framework of choice and equilibrium and of the issues of endogeneity and identification in empirical work. I find this confluence of the social sciences interesting and exciting. I don't expect complete reintegration of fields that separated more than a century ago; the benefits of specialization remain. But I do expect much closer communication and collaboration that will benefit research in all these fields.

applicability of game theory in certain real-world situations. A metaphorical interpretation of game-theoretic models can nonetheless hold significant value. Game theory can generally be used to deduce principles and insights from simplified models of reality. Simpler models are generally more prescriptive. Oftentimes, when game theory is applied in more complex situations, it results in no outcome or in multiple equilibria. In such cases complex modeling may lose its predictive ability.¹⁷ One objective of microeconomic modeling is to simulate qualitatively the type of environment being studied. Useful insights into an issue or behavior of practical relevance can be then deduced.

A simple game-theoretic framework has several advantages for strategic management.¹⁸ First, it provides an *audit track* that enables researchers and practitioners to go back to basic premises. Management should formulate the basic assumptions explicitly and consider whether they are of practical relevance. Second, it offers a methodology that is conducive to rigorous analysis and can help derive *novel insights*, which might be counterintuitive in some cases. Such insights may hardly stem from a “boxes-and-arrows” conceptual framework.¹⁹ Finally, it helps bring discipline by enforcing a *common language* that enables researchers and managers to compare results and refine earlier models.²⁰ In view of such potential extensions, game theory holds out considerable promise for

17. See Grant (2005, p. 111).

18. This discussion follows Saloner (1991, pp. 120–25, 127).

19. Saloner (1991) includes Porter's (1980) five-forces framework among these conceptual frameworks for strategic management. A game-theoretic refinement of Porter's (1980) framework is offered by Brandenburg and Nalebuff (1996).

20. Some microeconomic models are quite tractable for studying new problems. Cournot and Bertrand duopoly models discussed in chapter 3 form the basis for many industrial organization setups which are often much more complex. For instance, the commitment theory addressed in chapter 4 can be understood in light of these two pillar models.

studying human interactions. This explains the success of game theory particularly in economics and strategic management. The following three fields have greatly benefited from game-theoretic modeling:²¹

- **Industrial organization** This field focuses on strategic interactions arising in the *external* environment of the firm, addressing issues such as competitive interactions in oligopolies, first- and second-mover advantages, firm entry and exit decisions, strategic commitment, reputation, signaling and information asymmetries among different players in an industry.

- **Organization theory** This field focuses on the firm's *internal* or organizational aspects such as vertical and horizontal scope and conflicting incentives inside an organization (e.g., optimal compensation schemes).²²

- **Interaction between the internal and external environment of the firm** This area addresses issues at their *interface* like optimal incentive schemes in oligopolistic market structures,²³ organizational design to achieve competitive advantage, cooperation versus competition in R&D.²⁴

A good understanding of the competitive environment will thus enable managers to ascertain the strategic implications of their actions in the marketplace and determine how they should behave. A normative role for the strategic management literature is to provide a broad qualitative understanding of such strategic interactions and give qualitative prescriptions for managerial action.²⁵ Although game theory has witnessed rapid developments since the 1950s, its use for practical strategic management purposes has remained limited so far.²⁶ Nevertheless, some managers already incorporate game-theoretic thinking into their planning.

21. This discussion follows Saloner (1991, pp. 119–20).

22. Theories of the firm attempt to explain why firms exist and operate as they do. They include property-rights theory, incentive-system theory, rent-seeking theory, adaptation theory, and contract theory.

23. Ferschtman and Judd (1987), for example, argue that in case of product market competition, a firm has an incentive to design incentive schemes in a way that would not be optimal for a stand-alone organization. In their model, managers have an incentive to maximize output in a quantity competition setting, which makes the firm better off since the rival interprets the incentive contract as a commitment. This exemplifies the possible use of industrial organization thinking to better the understanding of firms' organizational design.

24. D'Apremont and Jacquemin (1988) analyze the effect of R&D spillovers on the incentive to cooperate or compete during the R&D stage and the market competition stage.

25. See Saloner (1991, pp. 107–31).

26. In politics, game theory has been used to analyze the 1962 Cuban missile crisis, President Reagan's 1982 tax cut, and certain public auctions.

1.4 An Integrative Approach to Strategy

Both corporate finance and game theory provide useful insights for strategic management. As discussed by Jean Tirole in box 1.9, the interface between finance and game theory enables attaining a better understanding on a number of firm- or market-related issues. Viewed separately, however, these approaches have limited applicability. Integrating these approaches in a consistent manner is at the core of the option games approach. Standard real options analysis overcomes many of the drawbacks of the NPV approach but neglects other aspects. When management assesses its real options, it must determine whether the benefits resulting from the exercise of its options are fully appropriable. Kester (1984) distinguishes two categories of real options depending on whether the benefits are proprietary or shared. If management has an exclusive exercise right, retaining all potential benefits for itself, the investment opportunity is a *proprietary option*.²⁷ When the firm is not in a position to appropriate all of the project's benefits for itself but rivals share the same opportunity, it is a *shared option*.²⁸ In this case, the presence of market contenders introduces strategic externalities (positive or negative) that can significantly affect the value and optimal exercise strategy of the firms' real options. The value loss resulting from strategic interactions is seen as a *competitive value erosion*. Standard or naïve real options analysis typically assumes a proprietary or monopolistic mind-set, ignoring such shared options.²⁹ A firm here formulates its investment decisions in isolation, disregarding interactive competition.

27. Rivals' investment decisions have no material impact on project values or optimal strategies. For instance, a monopolist protected by significant entry barriers faces such a situation. Proprietary options are also encountered when a firm is granted an infinitely lived patent on a product that has no close substitutes or when it has unique know-how of a technological process.

28. Shared options include the opportunity to launch a new product that is unprotected from the entry of close substitutes, or the opportunity to penetrate a newly deregulated market.

29. One reason why strategic interactions among option holders are not typically considered in standard real options analysis is that early on real options were seen as an extension of standard option-pricing theory to real investment situations. In capital markets, except in special cases like valuation of warrants, strategic interactions among option holders rarely affect the asset or the option values. Certain continuous-time real option models attempt to account for market and competitive uncertainty in an exogenous manner, such as through a higher dividend yield or a jump process. These models represent an improvement over standard models developed with a monopolistic mind-set, but fall short of adequately accounting for the endogenous nature of strategic interactions in an oligopolistic setting. Trigeorgis (1991) discusses continuous-time real options models involving strategic uncertainty exogenously.

Box 1.9**Interview with Jean Tirole**

1. You have contributed greatly to extending game theory for the analysis of economic problems. What are the merits of this mathematical discipline for economic analysis? Which other social sciences do you believe can benefit from the use of game theory?

Game theory aims at describing and predicting behaviors in environments in which actors are interdependent and have potentially conflicting objectives. It deepens our understanding of when the quest for specific goals may lead to inefficiencies and of how players choose actions with an eye on changing other actors' incentives. As such, game theory applies to all social sciences and beyond. The most obvious applications, besides economics, include political sciences, sociology, law, and psychology. Psychology might look like an outlier as it usually focuses on the individual, but it is not. Experimental evidence confirms the old notion that we "play games with ourselves." These can be represented as games among successive incarnations of the self. Biologists use game theory to understand mutualism between species, inefficient signals, or fights. Computer scientists also take a keen interest in game theory. Part of the appeal of game theory is that it accommodates diverse objective functions, which enables us to conceptualize the behavior of different actors, from consumers to politicians, from firms to suborganisms. Game theory more and more integrates behavioral approaches. Mainstream game theory focuses on optimal strategies given the strategic interdependences and the actors' limited information and various constraints. This rational choice approach has served social sciences well by identifying the key strategic features of conflict situations. At the same time, limited cognition and various

Box 1.9
(continued)

behavioral biases are being increasingly incorporated into our thinking about strategic interactions, extending the reach of game theory beyond purely rational choice. Finally, experimental economists have been testing our equilibrium concepts and behavioral predictions, and empiricists use game theory to put more structure on their estimation strategies.

2. Your work on industrial organization has helped popularize this important discipline and extend its areas of application. Do you think industrial organization will become increasingly more useful for managerial practice and understanding or predicting of market developments?

Yes. Game theory and its applications to industrial organization have made their way into business books and have affected managerial practice. For example, concepts developed in industrial organization are used in deliberations on how to design new platforms and get all sides on board. Game theory is taught to MBAs and strategy textbooks now incorporate game-theoretic thinking. Game-theoretic analyses have become a language for antitrust practitioners to conceptualize impacts of behaviors on market outcomes. Empirical work on estimating demand and strategic choices of price and non-price competition also make substantial use of game-theoretic industrial organization.

3. Do you see a connection between industrial organization and corporate finance? In what ways? Can game theory help reshape corporate finance as it has reshaped standard microeconomics?

There is indeed a strong connection between industrial organization and finance. I am really happy that your book “cross-breeds” options theory and industrial organization and connects it to business, as this is an area of very fruitful cross-fertilization. Not only do finance and industrial organization share common tools (e.g., economics of incentives, game theory), they also interface in many areas. For example, it is hard to fully understand predation or entry into industries without understanding financial constraints and therefore corporate finance. Conversely, the industrial organization of finance and banking is a hot topic on our research agenda. Game theory has already made its way into various subfields of corporate finance: takeover strategies, liquidity hoarding, expectations of refinancing and bailouts, bank runs, issues of securities under asymmetric information, and conglomerate strategies are just a few examples. Many areas of corporate finance have benefited significantly from importing ideas coming from game theory.

Table 1.2
Comparison of main advantages and drawbacks of standard stand-alone approaches

Approach	Advantages	Drawbacks
Standard NPV	Easy to use; convincing logic; widely used; easy to communicate	Assumes precommitment to a given plan of action, often treating investment as a one-time decision (“invest now or never”); ignores flexibility to adapt to unexpected market developments or strategic interactions
Real options	Incorporates market uncertainty and managerial flexibility; recognizes that investment decisions can be delayed, staged, or adjusted under certain future contingencies	Typically applied to the valuation of a monopolist or proprietary option; ignores (endogenous) competitive interactions
Game theory	Incorporates competitive reactions endogenously; considers different player payoffs	Typically disregards market uncertainty involving stochastic variables

Game theory has been generally applied to studying strategic interactions in settings involving steady or deterministically changing states, where players could accurately predict the evolution of the external environment. Standard game theory falls short of explaining the firm’s incentive to stay flexible to react to unexpected developments. Under uncertainty this prescription of standard game theory is inadequate.³⁰ The main advantages and drawbacks of each stand-alone approach (standard NPV, standard real options analysis, and game theory) are summarized in table 1.2.

Many real-world problems, however, require a simultaneous assessment of both market (exogenous) as well as competitive (endogenous) uncertainty. Stand-alone NPV, real options analysis, and game theory alone fail in providing the necessary tool kit. The NPV paradigm deals with *static* situations where firms make now-or-never decisions or pre-commit to a certain plan of action. Real options analysis allows for

30. Different forms of uncertainty are considered in game theory. For instance, some solution concepts (e.g., Bayesian and perfect Bayesian equilibrium) are designed to address problems involving information uncertainty. This form of uncertainty is not equivalent to what we consider here. In stochastic environments, payoffs may be affected by exogenous factors or *shocks*, whose future values are not known with certainty but follow a known probability law. The appendix of the book provides a discussion of such stochastic processes.

Table 1.3
Classification of decision situations and relevant theories

		Decision theory (no strategic interaction)	Game theory (strategic interaction)
Static		Net present value (DCF) <i>Chapter 1</i>	Static industrial organization <i>Chapter 3</i>
Dynamic	Deterministic	Resource extraction/ forest economics <i>Chapter 9</i>	Dynamic industrial organization <i>Chapters 4, 11, 12</i>
	Stochastic	Real options analysis <i>Chapters 5, 9,</i> <i>appendix</i>	Option games <i>Chapter 6 onward</i>

dynamic decision-making in situations where firms face exogenous *stochastic* uncertainty.³¹ *Static* industrial organization (IO) has limited applicability to situations involving simultaneous games where firms are ignorant of both past and future actions and payoffs.³² *Dynamic* industrial organization analysis permits a long-term perspective but assumes steady state or a *deterministic* evolution of the market environment.³³ We here discuss an integrated approach employed to help overcome the shortcomings of stand-alone approaches, analyzing key value drivers concurrently. Option games are meant to capture *dynamic* strategic interactions in *stochastic* environments. Table 1.3 positions the option games approach within the traditional decision and game-theory paradigms.³⁴ We indicate in which chapters each approach is most relevant in the book.

The importance of incorporating options analysis and game theory is confirmed by the number of Nobel Prizes awarded in related fields. A

31. Real options analysis provides many applications for dynamic programming. The term “dynamic programming” was originally used by Bellman (1957) to describe a recursive process for solving dynamic problems. This method can be extended to stochastic environments. Stochastic dynamic programming or stochastic control is discussed by Harrison (1985), Dixit (1993), and Stokey (2008), with applications in economics and finance.

32. Static industrial organization rests on static game theory with the related notion of, for example, Nash or Bayesian Nash equilibria. See Osborne (2004) for an introduction.

33. Fudenberg and Tirole (1986) present a number of dynamic models of oligopoly. This field rests on dynamic game theory. It involves the use of “dynamic” solution concepts such as subgame perfect Nash, perfect Bayesian, or sequential equilibrium. A subfield is differential games that study dynamic strategic interactions in settings where an industry state evolves according to a differential equation. See Dockner et al. (2000) for an introduction to differential games.

34. Option games share some aspects with stochastic timing and differential games.

Table 1.4
Selected Nobel Prizes awarded in Economic Sciences

Year	Nobel Prize winner(s)	Noted contribution
2007	L. Hurwicz, E. S. Maskin, R. B. Myerson	For laying the foundations of mechanism design and contract theory
2005	R. J. Aumann, T. C. Schelling	For enhancing our understanding of conflict and cooperation through game theory analysis
2001	G. A. Akerlof, A. M. Spence, J. E. Stiglitz	For analyzing markets with asymmetric information
1997	R. C. Merton, M. S. Scholes	For developing the option pricing method to value derivatives (and thereby real options)
1994	J. C. Harsanyi, J. F. Nash Jr., R. Selten	For their analysis of equilibria in the theory of noncooperative games
1990	H. M. Markowitz, M. H. Miller, W. F. Sharpe	For their pioneering work in the theory of financial economics
1982	G. J. Stigler	For his studies of industrial structures, functioning of markets, and causes and effects of public regulation
1981	J. Tobin	For his analysis of financial markets, expenditure decisions, employment, production, and prices
1978	H. A. Simon	For his research into the decision-making process within economic organizations
1975	L. V. Kantorovich, T. C. Koopmans	For their contributions to the theory of optimum allocation of resources
1970	P. A. Samuelson	For developing dynamic economic theory and raising the rigor of analysis in economics

Source: Nobel Prize committee website.

selected list of Nobel Prize awards in economic sciences is shown in table 1.4. Real options analysis is a natural extension of major breakthrough developments in financial economics to real investments. It builds on the seminal works of Paul Samuelson, Robert C. Merton, Fischer Black, and Myron Scholes. Concurrently the analysis of industrial organization has been greatly facilitated by developments in game theory. Von Neumann, Morgenstern, and Nash have made significant early contributions to game theory. Selten, Harsanyi, Schelling, and Aumann also earned Nobel

Prizes for refinements to the theory.³⁵ Option games, being at the intersection of option and game theories, benefited from the cumulative developments in these subfields of economic sciences. Today option games represent a powerful strategic management tool that can guide practical managerial decisions in a competitive context, as discussed by Ferreira, Kar, and Trigeorgis (2009). It enables a more complete quantification of market opportunities while assessing the sensitivity of strategic decisions to exogenous variables (e.g., demand volatility, costs) and competitive interactions.

1.5 Overview and Organization of the Book

The book is organized in three parts. Part I, “Strategy, Games, and Options,” presents the three building blocks or prerequisite fields for the option games approach. Chapter 2, “Strategic Management and Competitive Advantage,” reviews the main strategic management paradigms used to analyze or explain a firm’s performance in creating value for shareholders. We describe industry and competitive analysis and discuss how to create sustainable competitive advantage in an industry utilizing generic competitive strategies. Chapters 3 and 4 on “Market Structure Games” introduce game theory principles and industrial organization concepts providing economic foundations for strategic management. Chapter 3, focusing on “Static Approaches,” discusses benchmark cases where firms interact in one-time situations. Quantity and price competition are discussed in detail. Chapter 4, focusing on “Dynamic Approaches,” supplements the previous analysis by allowing firms to interact in the marketplace over many periods, attempting in the long term to shape the market in their own advantage or collaborating with rivals for mutual benefit. Chapter 5 on “Uncertainty, Flexibility, and Real Options” discusses the strategy-formulation challenges facing the firm when the underlying market is uncertain. Motivated by various sources of uncertainty electricity utilities face today, we discuss how real options analysis can be used to analyze such situations, value strategic options, and optimally chose among them. We also briefly discuss discrete-time and continuous-time tools for the pricing of embedded real options. We ignore here the fact

35. Akerlof, Spence, Stiglitz, Hurwicz, Maskin, and Myerson won the Nobel Prize for insightful applications of game theory for the understanding of incentives in social groups (e.g., industrial organization, contract theory).

that many firms may face counteracting business opportunities affected by rival behavior.

Part II, “Option Games: Discrete-Time Analysis,” fleshes out in more detail in discrete time the integration of real options with game theory and industrial organization and explains how to capture the flexibility and strategic-interaction aspects of real investment situations. Chapter 6 presents core issues in option games analysis, namely optimal investment timing under uncertainty and competition and the trade-off between commitment and flexibility. We provide a number of examples to illustrate the discrete-time option games approach. Chapter 7, “Option to Invest,” rigorously sets the premise for analyzing option games in discrete time, building upon models developed in chapter 3. Chapter 8, “Innovation Investment in Two-Stage Games,” discusses at length the trade-off between commitment and flexibility in sequential investment settings. The focus, here, is on two-stage competition models where real options analysis tools are combined with industry organization insights. The two-stage analysis provides guidance into how and when strategic investments enhance value creation or are detrimental to the firm. We examine appropriate investment strategy applications in different settings, such as R&D and advertising.

Part III, entitled “Option Games: Continuous-Time Models,” extends the analysis of option games by use of continuous-time modeling techniques. Chapter 9, “Investment and Expansion Option: Monopoly,” introduces the methodology employed throughout part III and sets the benchmark case of a monopolist firm. Two categories of options are discussed, the option to invest in a new market and the option to expand an existing market. Chapter 10, “Oligopoly: Simultaneous Investment,” extends the analysis to simultaneous investment oligopoly markets. Chapter 11, “Leadership and Early-Mover Advantage,” discusses the appeal of having a competitive advantage to turn the investment-timing game into one’s own advantage. Chapter 12, “Preemption versus Cooperation in a Duopoly,” deals with preemptive investments and the possibility of tacit collusion among firms, delaying investment until a later date. Chapter 13, “Extensions and Other Applications,” provides a short overview of important contributions on various subjects and other applications discussed in the literature. The appendix that follows discusses the basics of stochastic processes and provides a compendium of tools in stochastic calculus and control for the more analytically minded reader. To smooth out the exposition in the text, part III occasionally refers to this appendix when a derivation is more involved.

Conclusion

In this introductory chapter we discussed key changes firms have faced over the past decades. We discussed the development and changes in a challenging business environment and the evolution of strategy, and examined to which extent the two pillar approaches underlying this book, namely game theory and real options analysis, can be rigorous and relevant for analyzing and understanding business strategies. We concluded with the need to combine both into an integrative option games approach.

Selected References

Grant (2005) discusses the role of strategy in corporate performance, stressing the need for sound strategy formulation based on consistent principles. Myers (1984) discusses the gap between financial theory and its practical implementation in corporate strategy, highlighting the differential insights corporate finance can add to strategy. Saloner (1991) and Rasmussen (2005) discuss the usefulness of game theory for strategic management, emphasizing its prescriptive value in competitive settings involving strategic interactions.

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