CHAPTER 1

INNOVATION AND THE MARKET

HOWARD FLOREY ARRIVED IN NEW YORK ON JULY 2, 1941 along with a member of his research team, Norman Heatley. Florey was the chair of the pathology department at Oxford University in Britain. For the previous few years he had been conducting research on penicillin with Heatley and Ernst Chain, a Jewish refugee from Germany. Alexander Fleming, a British doctor, had discovered penicillin in 1928. As was his custom, Fleming left out petri dishes in his laboratory that were inoculated with bacteria. A mold, later identified from the *Penicillium* family, contaminated one of the dishes, inhibiting the growth of the bacteria. Fleming dubbed the active substance secreted by the mold "penicillin" but was unable to separate it from the broth in which the mold grew to assess its therapeutic potential. Florey's lab picked up on Fleming's research roughly ten years later. Using a sample of Fleming's mold, they managed to isolate minute amounts of impure penicillin and test it in mice. Encouraged by the results, they next tried it out on a few dying patients.

Times were different, and human trials were much easier to arrange. They found an Oxford policeman who was near death. A simple prick from a rose thorn had caused him to contract an infection that led to the loss of an eye and abscesses that had spread all over his body. After getting an injection of penicillin, a miracle seemed in the offing as his condition greatly improved. But sufficient supplies of penicillin were lacking to continue his treatment. The situation got so desperate that they collected his urine and transported it by bicycle to the laboratory to extract unmetabolized penicillin in an effort known as the P-Patrol. Supplies ran out, however, and he died. But penicillin's potential was clear, which was reinforced by the next patients they treated.*

* See Sheehan [1982, pp. 31–34] for the early experiments of Florey's lab with penicillin.

These experiments established that penicillin could be a powerful weapon to treat infection, but it would have to be produced on a much greater scale to be useful. Florey tried to get British firms involved in the effort, but they were preoccupied with World War II and were unreceptive. So he turned to the Rockefeller Foundation in the United States, which earlier had supported his research. He was given a grant of $6,000 to come to the United States to interest U.S. firms and the U.S. government in the mass production of penicillin (Neushul [1993, p. 167]). Thus, on the eve of Florey's trip to America in 1941, penicillin showed promise of being helpful in the fight against infection but could only be produced in minute amounts.

Within three years all was about to change. Dramatic clinical developments would prove that penicillin was a wonder drug, effective against an extraordinary range of conditions, including childhood killers rheumatic fever and pneumonia, venereal diseases syphilis and gonorrhea, and deadly infections incurred by burn victims and wounded soldiers. By D-day in June 1944, enough penicillin would be produced to meet all of the military's needs. A year later, penicillin would be widely supplied to civilians. All these developments would usher in a new era of medicine and with it a whole new industry. But when Florey embarked for the United States in July 1941, these possibilities could hardly be imagined.

Soon after they arrived, Florey and Heatley were directed to a government laboratory in Peoria, Illinois, that was exploring the use of deep fermentation techniques to develop new uses for surplus farm products. The lab conventionally used corn steep liquor, which is a by-product of the corn starch manufacturing process, in all of its fermentation efforts. It was discovered that corn steep liquor was an ideal medium in which to grow the *Penicillium* mold, increasing the output of penicillin twelvefold (Sheehan [1982, p. 67]). And it could be grown in a submerged medium rather than in shallow layers in flasks, bottles, or pans, which it was estimated would have had to stretch from New York to San Francisco to meet the U.S. military's needs during the War (Brockman and Elder [1970, p. v]).

The findings regarding corn steep liquor were conveyed in a meeting in December 1941 with research and corporate heads from pharmaceutical companies Merck, Squibb, Pfizer, and Lederle. The meeting was organized by a committee appointed by the Office of Scientific Research and Development (OSRD), which was set up to coordinate scientific research for military purposes during World War II. Prior to the meeting, Merck, Squibb, and Pfizer had been experimenting in a desultory way with producing penicillin using the shallow culture approach (Sheehan [1982, p. 69]). Hearing about progress at the lab from the head of its fermentation division, Robert Coghill, galvanized their work on penicillin. Coghill later remarked that as a result of the lab's discoveries a new pharmaceutical industry was born.*

The OSRD sponsored an ambitious program involving several hundred scientists to synthesize penicillin in the laboratory, which at the time seemed like the more promising route toward the large-scale manufacture of penicillin. A sister federal agency sponsored research at a number of universities on various challenges associated with producing penicillin by growing the *Penicillium* mold, and it continued to support efforts at the government's Peoria lab to improve the natural production of penicillin.

The War Production Board, which was set up in 1942 to regulate production and allocation of materials during World War II, was also enlisted to help increase penicillin production. A program was set up to finance new production plants for qualifying firms and to allow for accelerated depreciation for private investments in penicillin production. More than 175 companies were considered for support. Twenty-one were selected based on their ability to contribute to the wartime effort. A total of $7.5 million ($108 million in 2015 dollars)[1] was spent by the Board on the construction of new plants and $22.6 million ($324 million in 2015 dollars) was invested by firms, much of which qualified for accelerated depreciation (Federal Trade Commission [1958, p. 52]). Firms were given regular reports on progress at the Peoria lab and other efforts supported by the OSRD and agreed to exchange information about their findings.

By 1943 penicillin's therapeutic properties had been established and the military recognized the benefits of using it on the battlefield to treat soldiers. By the second half of 1944, U.S. firms were widely producing penicillin using the submerged—or deep vat—method. Enough penicillin was produced to treat almost 250,000 patients per month, which was adequate to meet the military's demands on D-day and thereafter. Production tripled from the second half of 1944 to 1945, and by March 1945, producers and distributors were allowed to sell penicillin through normal channels. In contrast, in 1944 British firms were able to produce less than 2.5% of American production. They did not adopt submerged production until 1946, and only with U.S. help (Bud [2007, p. 49]). After

*Neushal [1993, Chapter 6] recounts the early developments in the United States regarding penicillin and the federal government, and Neushal [pp. 183–184] notes the effect of these efforts on private firms.

the War, U.S. firms vaulted into the forefront of the antibiotics revolution that penicillin had wrought.

How did this happen, and happen so quickly? Technological advances were made on numerous fronts. The *Penicillium* mold was adapted to grow in a submerged medium. Ways of sterilizing fermentation tanks from the outset and maintaining them free of foreign microorganisms for many days were developed. Better strains of molds were discovered. Precursors were added to the fermentation broth that increased yields and targeted new types of penicillin. Improved methods of isolating and purifying penicillin from the fermented broth were devised. The list goes on (Greene and Schmitz, Jr. [1970]).

Key to all these advances was the penicillin program sponsored and coordinated by the U.S. government. John Sheehan was working on penicillin at Merck during the War and later went on to successfully synthesize penicillin in the laboratory after everyone else had given up the effort. Reflecting on the developments that occurred during the War, he wrote:

> Only the federal government could have organized such a massive cooperative effort involving thirty-nine laboratories and at least a thousand chemists. Only the federal government could have eased the restrictions of anti-trust regulations that might have prevented the collaboration of otherwise competitive industries in their efforts to investigate penicillin and, eventually, produce and sell the wonder drug. Merck, Squibb, and Pfizer—the Big Three of the pharmaceutical industry—were the largest and most influential companies in this effort. They were not alone, however. Once the basic research was under way, another twenty or so pharmaceutical and chemical companies entered the field to produce penicillin and the chemicals needed for its production. Without a carefully defined working relationship among all these companies, the penicillin production program simply would not have taken place. (Sheehan [1982, p. 201])

Penicillin was the first of the antibiotics that unleashed a revolution in medicine and propelled U.S. firms to the forefront of the pharmaceutical industry. It is one of many triumphs in the United States in innovative industries. The term high-tech will be used to refer to the sector of the economy where technological progress is at the heart of competition among for-profit firms. This book is about the high-tech sector and how it operates in the United States.

The penicillin story that opens this book raises deep questions about how high-tech industries get started. Surely one of the great strengths of the United States in the high-tech sector is its reliance on the market. Government has to perform some basic functions such as providing for the common defense, educating the populace, funding basic research, and investing in infrastructure like roads and the Internet. But when it comes to high-tech products, where does the government's role begin and its responsibility end? Fleming and Florey's work was funded publicly in Britain. Without the wartime penicillin program sponsored and coordinated by the federal government, it seems doubtful that U.S. firms would have been in the vanguard of the antibiotics revolution unleashed by penicillin. But if private firms in the United States were making little progress on their own in penicillin and in just three years this was all transformed by a government effort, what does it say about the efficacy of the market in high-tech industries?

Questions like these abound about the high-tech sector in the United States. To answer them, six products that I have studied over the last two decades will be used as a laboratory to explore the high-tech sector: automobiles, pneumatic tires, TV receivers, semiconductors, lasers, and penicillin. Using a methodology that in many ways is a throwback to Darwin and evolutionary biologists, all the firms that ever produced these products are traced, including where they came from and how they performed. Marshaling evidence from many sources, I demonstrate that these six industries exemplify the highs and lows of American high-tech capitalism and buried in them are deep and important lessons about competition and technological progress. Indeed, I hope to convince readers by the end of the book that understanding these lessons can not only make us better workers and entrepreneurs but also show us how to shape and use public policies to make the high-tech sector perform better, to take it to new heights.

What is it about these products that drew my attention and on which I will base my claims? In their time, all of them were quintessentially high-tech and to a large extent still are. When each of the products was first produced, they were extraordinarily primitive yet sold for such high prices that few wanted or were able to afford them. But through continual innovations over many years in the products and the processes used to produce them, they became widely purchased. For example, consider the automobile industry. In 1908 Henry Ford introduced the Model T at a price of $850 (about $20,000 in 2015 dollars) when comparable cars sold for $2,000 to $3,000 (roughly $50,000 to $70,000 in 2015 dollars). Six years later the price of the Model T had been reduced by over half, to $360 ($8,400 in 2015 dollars), driven by a stream of production innovations culminating in the moving assembly line that reduced the time required to build auto chassis from twelve-and-a-half hours to less than two hours and more than doubled the number of automobiles produced per worker. But the industry was much more than Ford and the Model T. Just nine years later, in 1923, the number of automobiles produced per worker had more than doubled again through widespread innovations in equipment, machinery, body construction, and painting, among other factors. These advances took an industry that sold 23,000 cars in 1904 to one that sold 1.7 million cars in 1919 and 5.3 million in 1929, more than any other country or comparable region in the world (Klepper and Simons [1997]).

The industries that arose to produce the other five products went through similar transformations, providing a window into understanding the forces governing technological progress and economic growth in the United States. But it is the way that these forces played out in the six industries that makes them so compelling. For example, in the automobile, tire, TV receiver, and penicillin industries, a small number of firms came to dominate them for many years. Capitalism is built on the idea of competition among the many, but these industries gravitated away from this model. Why did this occur? Did it have something to do with innovation and technological change? Did it affect technological progress—did it eventually diminish the incentives of firms to innovate? Did it alter the character of innovations—did firms become more conservative and less aggressive about generating breakthrough innovations? Fortunately, the industries that were most dominated by a few firms did not start out that way, which provides an opportunity to analyze the forces that led to their domination. Some surprising conclusions emerge about how innovative competition shaped the structure of these industries and in turn promoted technological progress.

A majority of the industries also experienced great turnover in their leading firms, with famous firms like General Motors, Firestone, and Intel emerging out of the turnover. Indeed, the United States is famous for its entrepreneurial zeal that has led to the creation of so many successful firms in the high-tech sector. To understand this phenomenon, the origins of the leading firms in each of the six industries and the impetus for their formation are investigated. This reveals a process akin to biological evolution in which new firms are born (involuntarily) out of existing firms and inherit traits that influence their performance. As successful as the United States has been in generating great new high-tech firms, questions are raised about how policies adopted by states might be inhibiting the formation of such spinoff enterprises and the technological progress they generate.

Today, the most celebrated high-tech sector in the world is Silicon Valley in Northern California, which got its name from the semiconductor producers that concentrated there. Every region would like to be “the next Silicon Valley,” and every country in the world would like to grow its own Silicon Valley. But how did Silicon Valley become the center of the semiconductor industry? It is hard to point to any feature of the region that made it advantageous for semiconductor producers to locate there. Two of the other six industries also heavily concentrated in one region early on—autos around Detroit, Michigan, and tires around Akron, Ohio. Neither of these regions also had any compelling natural advantages for auto and tire producers to locate there. Indeed, between Silicon Valley, Detroit, and Akron we have three of the most famous industrial clusters without an obvious geographic rationale. This fact provides a unique opportunity to study whether similar forces were at work in the evolution of all three clusters and what if anything governments might do to replicate these forces.

While Silicon Valley is the envy of the world today, Detroit is the opposite—a once great region that has fallen on hard times and is the scene of great economic devastation. Its decline has paralleled the decline of the U.S. automobile industry and its three great firms, General Motors, Ford, and Chrysler. These firms were on the top of the world for over 40 years but have all declined precipitously in recent years, with the government recently stepping in to manage the bankruptcies of General Motors and Chrysler to avert an apocalyptic collapse. Remarkably, two of the other industries—TV receivers and tires—went through similar if not more extreme declines, providing an unusual opportunity to study industrial extinction.

The specter of government policy looms throughout the six industries. We tend to think of the high-tech sector operating independently of government, which is how many Americans prefer it. The wartime penicillin program clearly breaks this mold, but it turns out that the government, in the form of the military, was also influential in the early years of the semiconductor, laser, and to some degree TV receiver industries. The question that is analyzed in all four industries is whether society’s interests were promoted by the involvement of the government and how government policy might beneficially shape other high-tech industries when they are young.

Economics is conventionally divided into macroeconomics, which is the study of aggregate phenomena like inflation and unemployment, and microeconomics, which is the study of individual markets. One of my colleagues calls the methodology I use to study the evolution of new industries *nanoeconomics* to signify digging beneath the surface of markets to understand the forces that drive their formation and functioning. Every firm that entered an industry and the years they produced are tracked down, usually through annual rosters of producers compiled in buyers' guides and marketing volumes. The geographic and intellectual backgrounds of the firms are traced through searches of firm directories, announcements of new firms in trade journals, and sometimes even obituaries of firm founders. The history of innovation and the leading innovators are reconstructed by sifting through hundreds or even thousands of patents. The best performers are identified by searching for data on the periodic market shares of the leading producers. Inevitably, this kind of reconstruction is imperfect, reflecting limitations of the sources available to track any given industry. Seemingly arbitrary rules and judgments are required to make headway, and these will be spelled out carefully, mostly in footnotes to avoid interrupting the text.

Only six industries are featured in the book because the nanoeconomic reconstruction of an industry's evolution can be quite challenging. Finding the requisite sources typically requires being immersed in an industry's history. Understanding innovation requires studying an industry's scientific and technological heritage. Making sense of all the information collected requires developing a theory of the main forces governing an industry's evolution. This can be an arduous effort for even one industry, which is why evidence from only six industries is featured in this work.

Each chapter explores a different question about how the industries evolved using a mix of nanoeconomic evidence, theorizing, and case studies. Chapter 2 begins by focusing on what is called the industry life cycle. Innovative industries pass through various stages of development, like humans. At first, firms flood into an industry, but after a certain point the number of firms begins to decline despite continued growth in the output of the industry. When this process is particularly severe, only a few dominant firms are left standing at the end.

The automobile industry is a quintessential example. The longtime leaders of the industry—General Motors, Ford, and Chrysler—became three of the largest firms in the world and were household names to Americans. They dominated the U.S. industry by 1930, accounting for over 80% of its output, and maintained their dominance for many years afterward. But at its outset the industry had hundreds of competitors—at its peak in 1909 more than 270 firms in the U.S. industry produced automobiles on a regular basis. The next twenty years were an extraordinary period of prosperity in the industry. Americans clamored to buy autos, causing production to rise by an average of over 18% per year, but the number of producers declined steadily. The decline picked up steam in the 1920s, and by the start of the Great Depression in 1929 only 28 firms were still producing autos. By the time the United States entered World War II at the end of 1941, the number of U.S. automobile producers had dwindled to nine.

While the shakeout of producers in autos was particularly severe, shakeouts were also common in the other industries studied. The key questions studied in Chapter 2 are why shakeouts occur in innovative industries and how shakeouts affect technological progress and the welfare of society. Competition is generally viewed as key to the functioning of markets, and the job of antitrust policy is to maintain competition. But at first, and for quite a long time, the emergence of dominant firms in high-tech industries is potentially a great spur to technological progress. Vigorously enforcing competition can undermine technological progress and jeopardize breakthrough innovations. Three great advances of the twentieth century will be considered to illustrate the potential benefits to society of allowing a market to be dominated by a single firm, especially a market as large as the United States: mass production of automobiles, color TVs, and microprocessors.

Chapter 3 focuses on where the firms come from that ultimately dominate high-tech industries. Every country, every region, wants to develop these firms. How has the United States generated so many of them? In penicillin production, the early leaders—Pfizer, Merck, and Squibb—emerged from related industries. This is common in high-tech industries. So if a region does not have distinguished firms in related industries, it is not likely to prosper in a new high-tech industry if it sits back and leaves things to the market.

But that is only the first step. In many high-tech industries, the early leaders get displaced by new firms. Remarkably, most of these new firms are spinoffs that emerge from the leaders of the industry, founded by employees of the better incumbents. Chapter 3 explores the spinoff process in the six industries, the kinds of firms that spawn the most spinoffs, and the circumstances that spur the formation of spinoffs.

Delving into the process that generates spinoffs conjures up a biological metaphor in which spinoffs are involuntarily born out of their parents and inherit knowledge—the industrial counterpart of genes—from their unwitting parents. Detailed case studies of the formation of some of the leading spinoffs in the automobile and semiconductor industries are featured to help understand the impetus for spinoffs. The basic story is repeated over and over again. Innovative employees are thwarted and leave in frustration to pursue their agendas in their own firms. Surprisingly, it is not uncommon for leading firms to become controlled by managers with limited decision-making skills. This can create a volatile environment for employees to break off and form their own spinoff firms.

At one level, spinoffs can harm their parents by competing with them for customers and employees. At another level, spinoffs are often pioneers of major innovations their parents decline to pursue. Chapter 3 demonstrates that spinoffs can be tremendous assets that propel industries to new technological heights. Yet many states give incumbent firms the power to suppress spinoffs by enabling them to limit the mobility of their employees under the guise of protecting their intellectual property. Not only do employees become captives—modern indentured servants—but spinoffs can be stifled, destroying the golden eggs laid by the proverbial goose.

Chapter 4 considers industry clusters, in which firms in an industry congregate in one or a few regions. Clusters are commonly thought of as great national assets that help a country compete internationally. The conventional view of clusters is that they emerge because of the benefits enjoyed by their denizens—firms in clusters have a richer pool of labor to choose from, employees in clusters move more often between firms and in the process spread new ideas, and specialized suppliers and buyers are attracted to clusters, facilitating transactions. When new firms locate in a cluster the other firms located there benefit, but the new firms do not consider these effects when they choose where to locate. Therefore, private benefits fall short of the total social benefit of clustering (there is a "positive externality," to use an economist's jargon, operating in a cluster) and, consequently, many economists believe that governments need to undertake proactive policies to build up local industry clusters.

As already noted, automobiles, tires, and semiconductors were famously clustered geographically. The semiconductor industry is the prototype for what happened in all three industries. Following the commercialization of the transistor in 1949, the industry was initially concentrated in Boston, New York, and Los Angeles. The first semiconductor firm in Silicon Valley was founded in 1956 by William Shockley, who along with two other employees of Bell Labs shared the Nobel Prize that same year for the invention of the transistor nine years earlier. Shockley was a great recruiter and brought together a group of talented young employees to work in his new firm. They soon broke away to form their own firm, Fairchild Semiconductor, in frustration over his management policies. At first Fairchild was immensely successful, reflecting the innovative prowess of its founders. But like Shockley, the founders were scientists and engineers with little management experience. Combined with a few other key developments, this led to an explosive situation in which Fairchild ended up seeding Silicon Valley with an army of talented companies—sometimes called "the Fairchildren"—that caused the semiconductor industry to concentrate in Silicon Valley. Surprisingly, the rise of the automobile industry in Detroit 50 years earlier closely paralleled the development of the semiconductor industry in Silicon Valley, and the concentration of the tire industry in Akron was similar as well.

Focusing on the nano-origins of the leading firms in the Silicon Valley, Detroit, and Akron clusters suggests that the clusters were not driven by the benefits of firms locating close to each other. Rather, key to the formation of all three clusters were spinoffs. Spinoffs do not venture far geographically when they start up, so once the spinoff process gets going in a region, a cluster builds up organically. Spinoffs are all about experimentation, so clusters tend to be engines of economic growth, solidifying the United States's high-tech preeminence. But it is not clear whether any benefits accrue to firms simply from locating in clusters, an observation that would help explain the success of Texas Instruments and Motorola, two of the longtime leaders of the semiconductor industry that were located far from Silicon Valley. It is also not clear whether government efforts to engineer clusters by bringing like kinds of firms together in a narrow region will be productive.

Chapter 5 considers how high-tech industries get started, focusing on the potential role of government at their outset. Penicillin provides a role model. It was entirely a British invention, but the wartime penicillin program initiated by the U.S. government and the military was instrumental in the commercialization of penicillin and subsequent antibiotics by U.S. firms. World War II was an unusual era in which firms were no doubt more cooperative than usual, questioning whether government programs could be equally effective during peace time. But it turns out that the federal government and the military were also instrumental after the war in catalyzing the semiconductor and laser industries. They also engineered the formation of RCA after World War I and later influenced its patent licensing policies, which established a foundation for the radio and TV receiver industries.

The "market" is rife with limitations when it comes to high-tech products, particularly when they are young. U.S. capitalism is predicated on channeling individual initiative for the greater good, and much good it has generated, particularly in the high-tech sector. But without the government often getting new high-tech industries going, we might not be celebrating individual initiative today but rather lamenting its limitations.

Chapter 6 examines the opposite end of the spectrum when high-tech industries are mature and are dominated by a small number of firms. In many ways this is the dark side of U.S. high-tech capitalism, exemplified by the automobile, tire, and television receiver industries in modern times. The conventional, market-oriented view is that eventually all good things must come to an end, but the analysis of these three industries suggests that the market actually strangled itself. Prolonged shakeouts and dominance left just a few firms as the technological gatekeepers of their industry. Left to their own devices, they became conservative, slow to make or pick up on major technological developments. Yet they had accumulated such large profits and assets that they were able to survive for many years even as they sustained large losses. In effect, they were insulated from the discipline of the market. How such firms might be governed to avoid becoming ossified after many years of dominance will be considered.

The final chapter, chapter 7, synthesizes the findings of the substantive chapters regarding how high-tech industries evolve in the United States. The evidence for the six industries is supplemented with similar patterns in other U.S. industries and at times industry experiences in other parts of the world to buttress the findings for the six industries. Lessons abound for individuals, firms, regions, and nations. The last chapter is devoted to extracting these lessons so that societies can harness the talents and imagination of their members for the greatest good.

Two deep lessons emerge from the six industries about how the competitive process operates in high-tech products. The first is that technological progress requires experimentation at all levels. The wartime penicillin program was about experimentation on numerous fronts, some of it planned and some fortuitously conducted in government labs before the advent of penicillin. High-tech capitalism is all about experimentation. It is not a planned onslaught. Firms do not have grand visions about how to experiment and innovate, but decentralize such decisions to managers and employees. Yet people are extraordinarily limited in their ability to foresee the technological future. So, to make progress, a country needs many firms experimenting and competing.

In order for this to happen, talented individuals need to be able to leave established firms and set up competing firms in the same industry. Inevitably such firms end up exploiting knowledge their founders acquired at their previous employers. This knowledge is part of their employer's intellectual property. To make capitalism work in innovative industries, government must accept this reality and not go too far in enforcing intellectual property rights. Otherwise they will squelch the formation of the new firms required to advance new technologies. Intellectual property is different from other forms of private property in that it can be simultaneously used by multiple actors. And at times, government needs to stand by and let that happen, even at the expense of the firms that created the property in the first place.

The other major lesson that arises from the study of the six industries militates in the opposite direction. Too many firms in an industry can undermine each firm's incentive to innovate. Surprisingly, patents often provide little protection against innovations being copied. Innovators need to be able to embody their innovations in a large output to earn a sufficient return on their innovations. But when innovative industries are young, by definition no firm is very big. This is when government can be really helpful, as with penicillin. It can play a role as a buyer of innovative products, as a sponsor of technological experiments, and as a coordinator of firm efforts.

As new innovative industries evolve, some firms will get out ahead. They will be able to apply their innovations to a larger level of output than their competitors. This will provide them with a greater incentive to innovate than their rivals, causing new innovative industries to become dominated by a small number of firms. At first, this can be a tremendous boon to technological progress. Government needs to stand by and let it happen even if it means competition is compromised, as inevitably occurs. But protracted dominance can cause the leading firms to ossify and become impediments to technological progress. Left to its own devices, the market will eventually strangle itself. The challenge is whether public policies can be implemented to revitalize the powers of the market.

This creates quite a bit of tension when it comes to policy making in innovative industries. On the one hand, government cannot get too strict about enforcing either intellectual property or competition, especially when innovative industries are young. Moreover, it may need to step in and actively shape the evolution of innovative industries at their outset, including priming the pump for spinoffs to occur. If these steps are undertaken, no further involvement by government will be required when industries are young. But as new industries evolve, protracted dominance can lead to stagnation. If the market is left alone, once great firms and the industries they pioneered can be lost forever.

Hence, experimental capitalism requires a pragmatic approach to policy making. Historically the United States often struck the right balance between a doctrinaire attachment to the strengths of market decision making and an almost instinctive awareness of the limits of markets. It may not always have understood what it was doing, but for the most part it was successful. A major purpose of this book is to develop an intellectual foundation to interpret the successes of the United States in the high-tech sector. The collapse of once-great high-tech industries like automobiles when they became mature has also not been well understood, and another role of the book is to explain how such collapses have come about in order to figure out how they might be avoided in the future. Lessons abound not just for the United States, but for the rest of the world too.

There is always a question of what can be learned from the past that will help in the future. The world is no doubt changing fast. Throughout most of the twentieth century, the United States was by far the largest national market in the world, and this was certainly a key element in its historical success. But this advantage is beginning to wane. The world is far more interconnected through trade, reducing the importance of the size of any country's national market. Moreover, a number of areas are beginning to rival the United States in terms of the size of their markets. The European Union is roughly the same size as the United States. China is growing fast, and although poor by international standards, it is so large that it recently became the second biggest national market in the world. If its growth continues it seems only a matter time before it eclipses the United States in size, and India can't be too far behind. A number of countries, such as Japan, South Korea, and Taiwan, have figured out at times how to use government initiatives to stimulate the development of their high-tech industries to compete with the United States. And the United States is steadily falling behind the rest of the world in terms of its primary and secondary education systems.

All these developments, though, make it even more imperative for the United States to understand its past successes and failures in the high-tech sector. It is widely agreed that innovation is the key to economic growth. The United States's preeminence in innovation is being challenged from many quarters. If we don't figure out how we did it, we will soon be talking in past tense about why America's corporations (once) led the world.