INTRODUCTION

AMERICAN INDUSTRY faces a severe innovation crisis. Even though the United States had a positive trade balance in eleven high-tech areas, in 2002 the total balance of trade for these sectors went into deficit for the first time in the history of this country (see Figure I.1).[1] In 2008, the high-tech deficit reached $58 billion despite the eroding value of the dollar and the growth in aircraft exports.[2] More recently, however, this strong sector has been threatened by two-year delays in the production of Boeing's new plane, the Dreamliner.[3]

Other indicators point similarly in the direction of a decline in high technology. Several decades ago, the top twenty-five companies ranked according to their RDT (basic research, applied research, and product development) investments were all American companies. Now only nine are, and of these about half were reducing their RDT expenditures between 2003 and 2004—not a positive sign.[4] Not unexpectedly, an annual measure of radical innovations, the top 100 achievements in commercialized products selected by *R&D Magazine*, documents the same kind of decline during the same period. Recognizing that there are limitations in having only 100 awards for achievements in commercialized products and always 100 and that the selection process largely excludes the computer industry and the pharmaceutical industry, the proportion of awards given to the large industrial firms went from about 45 percent in the 1970s to 12 percent in the 1990s, and the downward trend has continued since then with these large firms receiving only six awards in 2006.[5] Still another indicator of technological decline is the proportion of all patents given to the major industrial research firms, especially General Electric (GE), Kodak, AT&T, DuPont, General Motors (GM), Dow Chemical, 3M, United

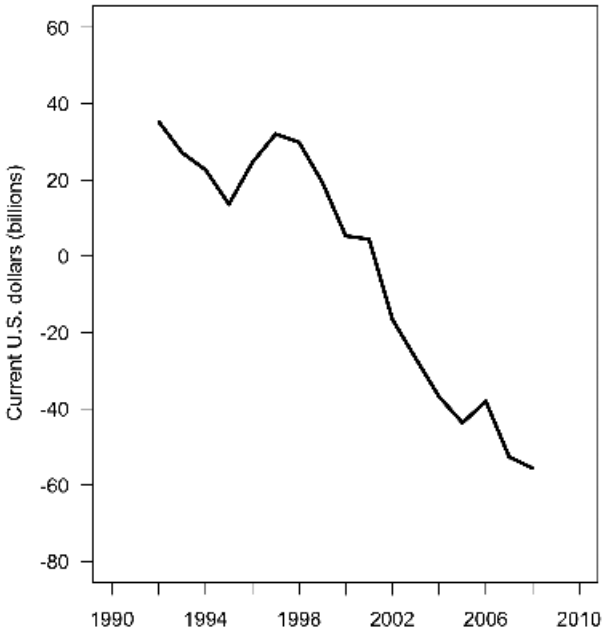

Figure I.1. Decline in U.S. trade balance across all high-tech sectors
Source: Generated from NSF 2010 data.

Technologies, and Ford went from 10 percent to 5 percent between 1972 and 2006 with the biggest drop-off occurring in the 1990s.[6] The concrete manifestations of this decline can be seen in the fading of Bell Labs, Xerox PARC, and other large industrial laboratories that previously produced scientific breakthroughs and technological advances. The major exceptions to these trends remain IBM, Microsoft, Intel, and Sun.

In a parallel manner, the federal government, although it had consistently spent more than 1 percent of gross domestic product (GDP) on RDT during the 1980s, is now spending only .8 percent, just as many foreign countries, especially China and India, are increasing their investments in RDT.[7] Fortunately, President Obama has promised to increase the budget to 3 percent of GDP by 2012. But how much money is allocated to research is only part of the problem; these increases will be achieved only over the years and, given current budget constraints, are anything but certain.

If these negative trade balances are *not* reversed and if American companies and the federal government do *not* invest in the right kinds of research in

this country that can restore the innovative edge, then the "rust belts" of the Midwest will be replicated in other parts of the country, particularly along the two coasts (see the pessimistic scenario in the report *Rising Above the Gathering Storm*).[8] The U.S. loss of jobs in the mass production industries of steel, cars, tires, toys, textiles, and others has had a devastating impact on the white and black working-class families resulting in divorce, single parenthood, and one-fifth of American children living in poverty without health insurance. As high-tech jobs are exported overseas and American high-tech industries fail to regain their innovative edge, imagine this same result for white and black middle-class families. Forrester Research estimates that 3.4 million U.S. jobs could be lost to offshoring by 2015, while other economists think that 14 million jobs are at risk.[9]

The United States has already begun to see the signs of this loss with stagnation in the average wages of those in the middle class during the past five years that has accelerated during the current economic crisis as evidenced by the growing deficit in high-tech sectors. The familiar examples of "offshore" middle-class occupations include call center technicians for computer problems, software programmers, and now even researchers. In recent years, IBM has increased its employee base in India from nine thousand to forty-three thousand while laying off thousands of employees in the United States and Europe.[10] So we can only applaud Jeffrey Immelt, the chief executive officer (CEO) of GE, who has said that it is time for American CEOs to rethink outsourcing and start thinking about how to build capabilities in the United States.[11]

The growth of high-tech industries in Asia represents a particular challenge to both the United States and Western Europe. The United States' share of world exports in all high-technology manufacturing declined between 2000 and 2009, specifically in the sectors of communications equipment, office machinery, scientific instruments, pharmaceuticals, and aircraft. Furthermore, it is not just India and China that are players in the global market place. A variety of developing countries are creating dominant niches in particular high-tech markets: Brazil in executive jets, South Korea in dynamic random access memory (DRAM) chips, Finland in cell phones, and Taiwan in boutique chips. Acer, a firm in Taiwan, is poised to overtake Dell as the world's second-largest producer of personal computers, a high-tech area that once was largely owned by American companies.[12] But as a sign that there are also successes in the United States, as this book is going to press, Hewlett-Packard

launched a new printer that could receive e-mail messages.[13] Whether this new niche will grow and whether it can be protected by patents remains to be seen, but it does indicate that some American companies remain highly innovative and also how much the success of the United States depends upon being first. Israel's firm Teva now fills more than 600 million prescriptions in the United States, more than Pfizer, Novartis, and Merck combined.[14] Nor should we forget the success of India's pharmaceutical companies in being able to work around the patents held by the American and British pharmaceutical companies. Some of the developed countries are also creating new niches in high-tech areas, such as Denmark in turbines for windmills as an alternative source of energy. France sells metro systems as complete packages, and Germany retains high-quality niches in many products. If the decline in high-tech exports follows the same curve as the steady decrease in the general balance of payments, then we can easily imagine a doubling in the proportion of children living in poverty, in the divorce rate, and in the numbers of homeless in the United States. Therefore, restoring the innovation edge is imperative not only for economic reasons but for social ones as well.

The extent of the innovation crisis can be documented in the increasing number of reports and books that recommended corrective action. First, in December 2004 the Council on Competitiveness' Task Force on the Future of American Innovation recommended that the federal government "increase significantly the research budgets of agencies that support basic research in the physical sciences and engineering, and complete the commitment to double the NSF budget. These increases should strive to ensure that the federal commitment of research to all federal agencies totals one percent of U.S. GDP."[15] Next came the National Academy of Science (Augustine, 2005) assessment, which went further in advocating varied action steps, most of them involving investments in scientific research and education. Concomitantly, various books have appeared with titles like *Innovation Nation* and *Closing the Innovation Gap* with similar appeals for more funding and the training of more scientists and engineers.[16]

While agreeing with these general recommendations, this book is about how to manage the money once it is provided and how the scientists and engineers should be organized. *The key idea is that restoring the innovation edge is not simply one of providing more money or training more scientists and engineers—as important as this is—but understanding what obstacles and blockages are causing the crisis and eliminating them.*

Before discussing these obstacles, perhaps we should recognize one perceptional handicap: Most Americans do not perceive that there is an innovation crisis! In giving talks to various policy groups and in academic settings, I have been amazed at the number of people who do not know the facts presented previously in this Introduction. Many reporters and op-ed writers in our newspapers, magazines, and journals keep saying that the United States is the most innovative country in the world.

Few people perceive that there is a crisis because (1) most people are unaware of the data on the trade balances in high-tech sectors discussed earlier; (2) the recent crises in housing and derivatives as well as the debates about health care reform have pushed the discussion of innovation, which was an important topic from 2004 to 2007, off both the front and op-ed pages as well as from the business section of the major newspapers; (3) paradoxically, a number of local and national success stories in innovation have made it difficult for many to think that we are not innovative enough; and (4) finally, perhaps the most important reason, the concept of productivity and the way in which it is measured have provided us with a false sense of confidence about how well the U.S. economy is performing over the long term as distinct from the current recession. According to this measure, we have the highest per capita GDP, thus leading individuals to believe that we are highly innovative. The problem is that this standard is not a measure of innovation except somewhat indirectly.

Although there are clear signs of a crisis in the data presented at the beginning of this introduction, these data are reported in the National Science Foundation (NSF) *Science and Engineering Indicators*, which is of interest to only a small group of policy makers concerned about science and technology. When I give talks about this problem I have asked the audience how many were aware of the data, and most were not. The major exceptions have been policy makers. The NSF has established a new program of research on the Science of Science and Innovation Policy to develop answers to this problem. In addition, a coordinating committee that unites the evaluation officers of twelve federal agencies has been created to share ideas while the Office of Management and Budget (OMB) has called for research about innovation. It may be a small circle inside the Beltway of the nation's capital, but clearly the experts are worried.

The period 2008–10 with a big housing bubble that burst with drastic consequences for many families, the near financial collapse of the major banks

worldwide, and most spectacularly, the rise of unemployment to 10 percent have focused most people's minds on other issues, and yet these issues are clearly related to the innovation crisis. If we are to recapture the lost employment of this past decade, we need to develop innovative products and services that sell on the international markets and provide us with positive trade balances. The important point about the lack of innovation and its impact on unemployment is that this problem has been slowly growing since the 1960s; this recession, with the collapse of the automobile industry, has only made it highly apparent and made it appear to be a temporary situation.

Another reason why people fail to perceive the extent of the crisis is that there are many innovation success stories in the newspapers every month, on both the local level with new start-up companies or in the annual lists of 100 innovative companies found in *Forbes Magazine*, as well as the giants of the computer and Internet industries such as Intel, Apple, Google, Amazon, Facebook, and Microsoft. The highly visible success of first iPhone and now iPad certainly calls attention to Apple's innovativeness. Recently Apple announced the fourth version of its iPhone with a sharper screen and the possibility of video-calling.[17] But as I discuss in Chapter 5, most of the components are made overseas, and thus this innovation does not help American employment. In Chapter 6, I detail a number of areas where the United States invented the technology but then lost control of it because other countries kept improving upon the technology. Later in this Introduction, I analyze the case of robotics. The continued successes in medical research are reported frequently on the various television news programs. Just recently, a new drug for prostate cancer was approved by the Food and Drug Administration (FDA). Yet, we have negative trade balances in both information technology and the health sciences. Thus these reported success stories about innovative products are obscuring the reality of economic failure. And this says nothing about the much larger deficits in the medium- and low-tech sectors where there has been much less innovation, which has been made highly visible with the failure in the automobile industry. As a matter of interest, while the crises of 2008–10 with its impact on the dollar reduced somewhat the extent of the negative trade balances in the low- and medium-tech sectors, it has had no effect on the high-tech sectors.[18] This is further evidence that in these sectors, people do not respond as much to price as to the technological sophistication, quality, and other characteristics. (For a discussion of these issues, see Chapter 1.).

But it is probably the local success stories of start-ups reported in the business sections of our newspapers and made into cases for business students to study that lead the average educated reader to conclude that there is no innovation crisis. Let me provide a few local examples of firms founded in Maryland in the mid-1990s that have become national successes. Honest Tea started when a runner wanted to have good flavored drinks without too much sugar. The company, which was founded in 1996, obtained is first major contract with Whole Foods (Fresh Foods at the time) in 1999. It followed the policy of inventing new tea flavors every year, recognizing that the contemporary consumer has highly varied and customized tastes (see Chapter 1). Because of these successful product launches and Honest Tea's large market niche, Coca-Cola bought a 30 percent interest in the company in 2009.

Another local example in Maryland is Under Armour, which was created by a former University of Maryland football player, at about the same time. Again, it was a similar simple insight, providing athletes with performance-enhancing underwear that did not absorb sweat and kept them cool (i.e., not using cotton). Again, it should be noted that this is a market niche in a highly competitive market dominated by giants such as Nike, Reebok, and Puma. Starting with contracts with major athletic programs, the company has grown rapidly via a policy of product innovation. In 2010 it had almost $1 billion in sales and 10 percent of the high-performance market. These examples of local start-ups can be repeated across many regions of the United States, and their success does make Americans feel that the country is innovative. But again in both cases, it does not mean more manufacturing jobs because the tea and the cloth are imported.

The most important reason, however, why the crisis in innovation is not perceived as such is because of the way in which productivity in the United States is measured. The Department of Labor measures the total number of hours used to produce a unit of goods. By this measure, as the number of work hours declines, the United States becomes more productive. Statisticians at the Department of Labor admit that this standard of measurement is a difficulty. But the problem is that this measure does not include the number of hours of work *outside* the country involved in the production of the same unit of good.[19] Thus if Apple or Under Armour import most of their materials, as they do, they appear to be more productive than they actually are. For example, when earlier tiers in the electronics supply chain, such as semiconductor devices and printed circuit boards, are offshored and these components are imported at lower

prices, the remaining downstream domestic industries realize a measured increase in productivity; however, the employment effect is negative.[20] Another problem with this measure of productivity is that it does not include the number of new products or new manufacturing processes that have been developed by American businesses, whether small or large.

But there is another way in which productivity can be misleading if emphasized too much by business elites and policy makers. Productivity measures efficiency or the conservation of resources, whereas measuring innovation is about counting the number of new products and the solving of problems. Thus, a focus on innovation is not only desirable for business growth and creation of jobs, but it is worth emphasizing because it leads to at least partial solutions for the difficult problems that face society. Whether the product is energy-efficient cars, underwear that does not absorb sweat, powerful computers, e-book readers such as the Kindle, or sugarless cookies, or whether the service is a better treatment for breast cancer, more effective screening techniques for terrorists, or a new educational program for the mentally challenged, innovation should be the goal, not efficiency.

At the same time, these two ideas are not always in conflict. One important kind of innovation, new technologies for the production of products or the provision of services, usually reduces the costs involved for any given level of quality. In Chapter 1, I advocate developing a third stage of manufacturing as one way of getting ahead of the innovative curve. In Chapters 5 and 6, I place considerable emphasis on manufacturing because of its implications for employment. In the following section, I discuss the innovation crises from a different perspective.

HOW THE PERSPECTIVE OF THIS BOOK IS DIFFERENT

The major way in which this book is different from current policy discussions is that it focuses on how to manage the innovation process from scientific breakthrough to success in international trade. The focus is always on how to produce radical product and process innovations, both in the private or economic sectors (mainly high-tech industries) and in the noneconomic or public sectors (health, education, homeland security). The public sector is as important as the private sector not only because jobs can be created in these sectors—health has been a major growth industry as its percentage of GDP approaches 16 percent—but because radical innovations help us to extend life, to continue with the health example, improve thinking skills, and reduce risks of terrorist attacks.