Wired for Innovation

How Information Technology Is Reshaping the Economy

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1 Technology, Innovation, and Productivity in the Information Age

In 1913, $403 was the average income per person in the United States, amounting to a little less than $35 a month.[1] To be sure, $403 went a lot further back then than it does today. A pack of cigarettes cost 15 cents, a bottle of Coca-Cola 5 cents, and a dozen eggs 50 cents. If you wanted to mail a letter, the stamp cost you only 2 cents. You could buy a motorcycle for $200. If you were wealthy, you could buy a new Reo automobile for $1,095, nearly three times the average person's annual income. The Dow Jones Industrial Average was below 80, and an ounce of gold was worth $20.67.

In 2008, the average income per person in the United States was $46,842—more than 115 times as much as in 1913.[2] At the end of 2008, a dozen eggs cost about $1.83,[3] a stamp was 42 cents, and the average price of a new car was $28,350.[4] The Dow Jones was above 8,700, and gold was about $884 an ounce.[5]

How do we correct for the erosion in the value of the dollar created by more than 90 years of inflation? Typically, the federal government uses a monthly measure called the Consumer Price Index (CPI) to track changes in the prices of thousands of consumer goods, including eggs, stamps, and cigarettes. According to the Bureau of Labor Statistics, prices, on average, have increased by a factor of nearly 22 since 1913.[6] On the face of it, this means that it would cost 21.7 times $403, or about $8,745, to purchase in 2008 a basket of goods and services equivalent to what could have been bought for $403 in 1913.

But think of all of the products and services you use today that were not available at any price in 1913. The list would be far too long to print here. Suffice it to say that a 1913 Reo didn't come with power steering, power windows, air conditioning, anti-lock brakes, automatic transmission, or airbags. Measuring the average prices will give you some idea of the cost but not the quality of living in these different eras.

Why are so many more high-quality products available today? Why are we so much wealthier today than people were in 1913? The one-word answer is the most important determinant of a country's standard of living: productivity. Productivity is easy to define: It is simply the ratio of output to input. However, it can be very difficult to measure. Output includes not only the number of items produced but also their quality, fit, timeliness, and other tangible and intangible characteristics that create value for the consumer. Similarly, the denominator of the ratio (input) should adjust for labor quality, and when measuring multi-factor productivity the denominator should also adjust for other inputs such as capital.[6] Because capital inputs are often difficult to measure accurately, a commonly used measure of productivity is labor productivity, which is output per hour worked. Amusingly, while we live in the "information age," in many ways we have worse information about the nature of output and input than we did 50 years ago, when simpler commodities like steel and wheat were a greater share of the economy.

Productivity growth makes a worker's labor more valuable and makes the goods produced relatively less costly. Over time, what will separate the rich countries from the poor countries is their productivity growth. In standard growth accounting for countries, output growth is composed of two primary sources: growth of hours worked and productivity growth. For example, if productivity is growing at 2 percent per year and the population is growing at 1 percent per year,[7] total output will grow at about 3 percent per year.

When we talk about standard of living, output per person (or income per capita) is the most important metric. Total output is not as relevant. Here is why: Suppose productivity growth was 0 percent per year, and population growth went up to 2 percent. Then aggregate economic output would also grow at 2 percent if output per person remained the same. The extra output, on average, would be divided among the population. Thus, if a country wants to increase its standard of living, it has to increase its output per person. In the long run, the only way to do so is to increase productivity.

Even changes of tenths of a point per year in productivity growth could mean very large changes in quality of life when compounded over several decades. This leads to the question of how countries can achieve greater productivity growth. While the answer includes strong institutions, the rule of law, and investments in education, in this work we focus on two other major contributors to productivity improvements: technology and innovation.

Economists like to tell an old joke about a drunk who is crawling around on the ground under a lamppost at night. A passer-by asks the drunk what he is doing under the lamppost, and the drunk replies that he is looking for his keys. “Did you lose them under the lamppost?” asks the passer-by. “No, I lost them over there,” says the drunk, pointing down the street, “but the light is better over here.” In our view, this highlights an important risk in economic research on productivity. The temptation is to focus on relatively measurable sectors of the economy (such as manufacturing), and on tangible inputs and outputs, rather than on hard-to-measure but potentially more important sectors (such as services) and on intangible inputs and outputs. However, the effects of technology on productivity, innovation, economic growth, and consumer welfare go far beyond the easily measurable inputs and outputs. It may be clear that a new $5 million assembly line can crank out 8,000 widgets per day. But what is the value of the improved timeliness, product variety, and quality control that a new $5 million Enterprise Resource Planning (ERP) software implementation produces, and what is the cost of the organizational change needed to implement it?

We find that the most significant trend in the IT and productivity literature since 1995 is that it has been moving away from the old lamppost and looking for the keys where they had actually been dropped. Economists, rather than assume that technology is simply another type of ordinary capital investment, are increasingly trying to also measure other complementary investments to technology, such as training, consulting, testing, and process engineering. We also see better efforts to examine the value of product quality, timeliness, variety, convenience, and new products—factors that were often ignored in earlier calculations. But we still have a ways to go.

In the late 1990s, there was a financial bubble in the technology sector. One need not look further than the rise and fall of the NASDAQ index (figure 1.1), the rise and subsequent leveling off of the stock of computer assets in the economy (figure 1.2), or the decrease in the number of news stories about technology since 2001 (figure 1.3) to be lured into thinking that technology has reached the peak of its strategic value for businesses. In a provocative 2003 article that supports this philosophy, Nicholas Carr asserted that IT had reached the point of commoditization, and that the biggest risk to IT investment was

Figure 1.1
The NASDAQ index, 1995–2008. Source: Yahoo Finance.

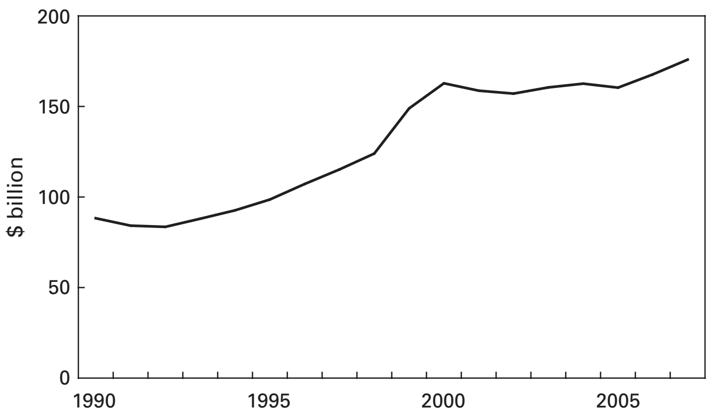

Figure 1.2
Current-cost net stock of computers and peripherals. Source: Bureau of Economic Analysis, Fixed Assets, table 2.1, "Current-Cost Net Stock of Private Fixed Assets, Equipment and Software, and Structures by Type," line 5. This refers to how much it would cost to replace computer equipment. For example, at the end of 1990 it would have cost $88 billion to replace all the computers held by business, in 1990 dollars, whereas at the end of 2007 it would have cost $176 billion in 2007 dollars to replace the computers in the economy.

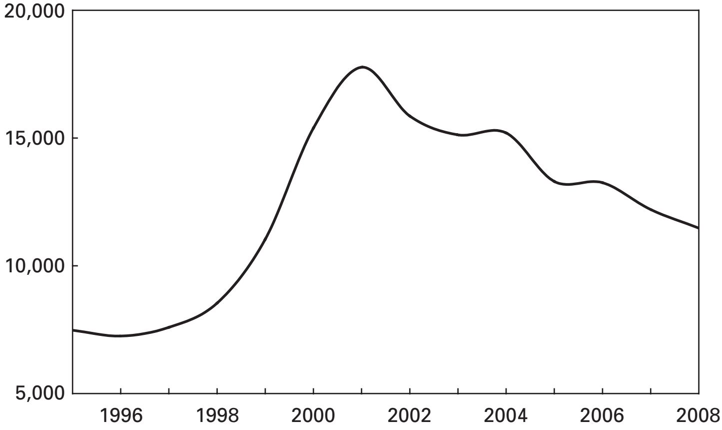

Figure 1.3
Number of stories mentioning "technology" in the *New York Times*, the *Wall Street Journal*, and the *Washington Post* combined. Source: Factiva.

overspending. "The opportunities for gaining IT-based advantages," Carr wrote, "are already dwindling. Best practices are now quickly built into software or otherwise replicated. And as for IT-spurred industry transformations, most of the ones that are going to happen have likely already happened or are in the process of happening. Industries and markets will continue to evolve, of course, and some will undergo fundamental changes. . . . While no one can say precisely when the buildout of an infrastructural technology has concluded, there are many signs that the IT buildout is much closer to its end than its beginning." (Carr 2003, p. 47) Carr concluded that companies should spend less on IT, and that technology should be a defensive investment, not an offensive one. His article resonated with many executives who had been lured in by the exuberance of the financial markets only to witness the subsequent destruction of trillions of dollars of market value.

However, we think that it was not the technology that was flawed, but that investors' projections of growth rates for emerging technologies were too optimistic. Some underlying trends in technology itself tell quite a different story. The real stock of computer hardware assets in the economy, adjusted for increasing quality and power, has continued to grow substantially (albeit at a slightly reduced pace since 2000). This adjusted quantity accounts for the increases in the "horsepower" of computing since 1990. As figure 1.4 shows, businesses held more than 30 times as much computing power at the end of 2007 as they did at the end of 1990.

Now consider innovation. As can be seen in figure 1.5, the number of annual patent applications in the United States has continued to grow steadily since 1996.

As we mentioned in the introduction, Gordon Moore predicted in 1965 that the number of transistors on memory microchips would double every year, and in 1975 he revised his prediction to every two years. What became known as Moore's Law has held for more than 40 years as if the financial bubbles and busts never occurred. In fact, according to data presented by the futurist Ray Kurzweil, if one goes back to the earliest days of

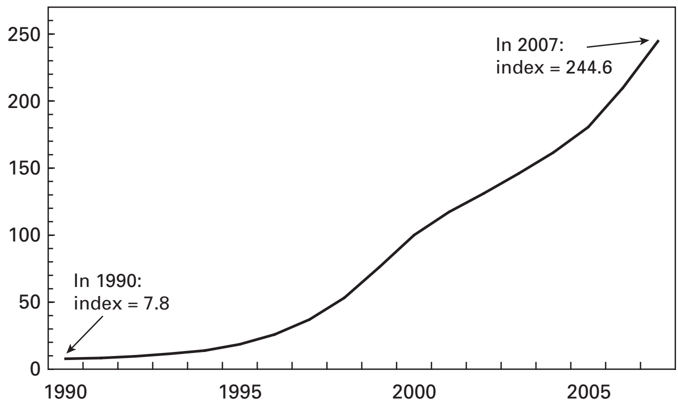

Figure 1.4
Quantity index of computer assets held by businesses in the U.S. economy, with year 2000 = 100. Source: Bureau of Economic Analysis. Fixed Assets table 2.2, "Chain-type quantity indexes for net stock of private fixed assets, equipment and software, and structures by type," line 5.

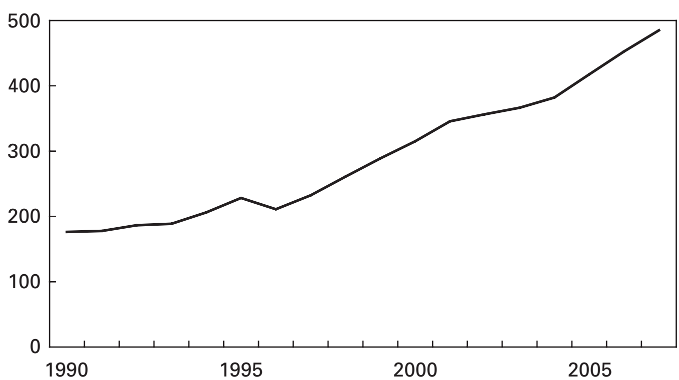

Figure 1.5
Total patent applications in the United States (thousands). Source: U.S. Patent and Trademark Office, Electronic Information Products Division Patent Technology Monitoring Branch (PTMB), "U.S. Patent Statistics Chart Calendar Years 1963–2007" (available at http://www.uspto.gov).

computers one can observe exponential growth in computing power for more than 100 years. Kurzweil also presents evidence demonstrating that over this longer time period Moore's Law may have accelerated. (See figure 1.6.) In figure 1.7, to put these changes into perspective, we offer an example from Intel.

While Moore's Law has steadily continued over the decades, 1995 marks a significant change in how IT could be changing competition in the United States. Figure 1.8 illustrates the performance gap in IT-using industries[8] at various levels of IT intensity. In that figure, all industries in the economy are grouped into three segments. The darkest curve represents those that use IT the most heavily, the next darkest line those that have moderate IT use, and the lightest line those with little IT use. The vertical axis shows the profit disparity between the most profitable companies in the segment and the least profitable as measured by the interquartile range (the 75th percentile minus the 25th percentile) of the average profit margin. Until the early 1980s, the size of differences in profit margins did not vary much with IT intensity—that is, leading firms were only a few percentage points better in profit margin than lagging firms in those industries. However, since the mid 1990s the interquartile range of profits for the heaviest users of IT has exploded. The difference between being a winner and being a lagging firm in IT-intensive industries is very large and growing. Using technology effectively matters more now than ever before.

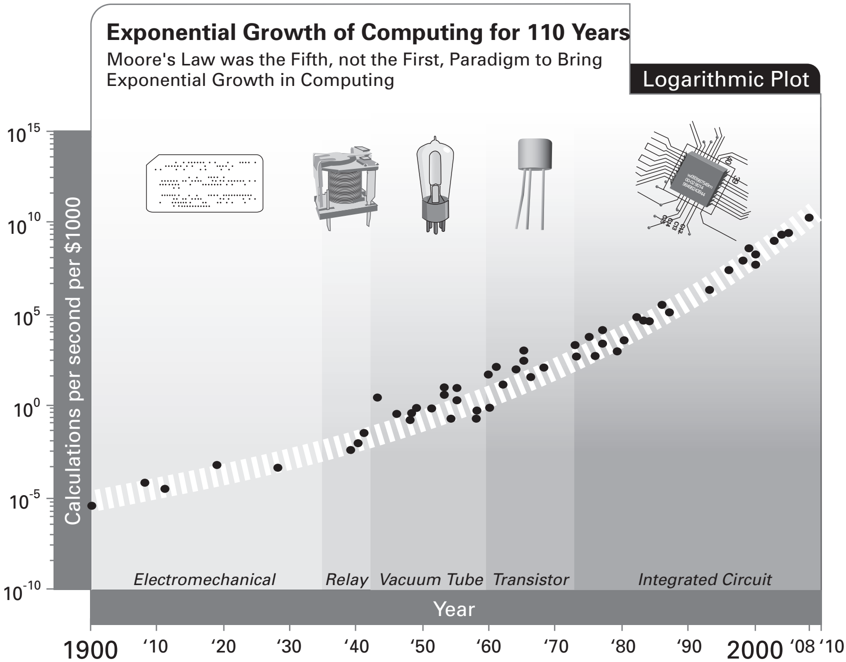

Figure 1.6
"Exponential growth of computing for 110 years." Source: KurzweilAI .net. Used with permission.

In light of the continued innovation in IT and the disparity of profits in IT-intensive industries, this is a very important time to study technology's strategic value to businesses.

In this book, we provide a guide for policy makers and economists who want to understand how information technology is transforming the economy and where it will

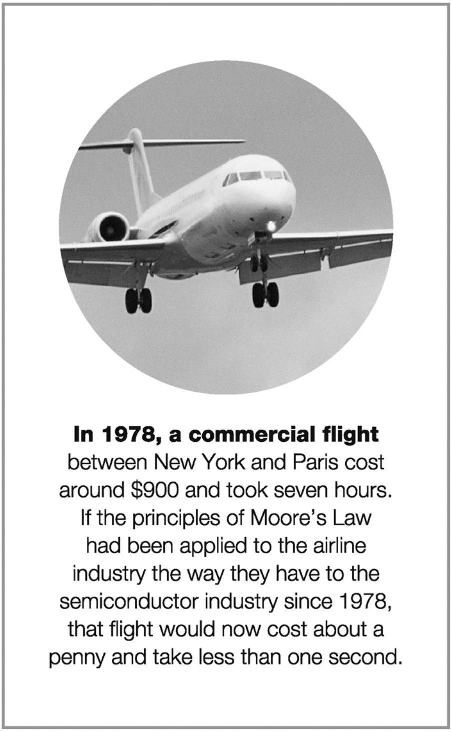

Figure 1.7
Moore's Law in perspective. Copyright 2005 Intel Corporation.

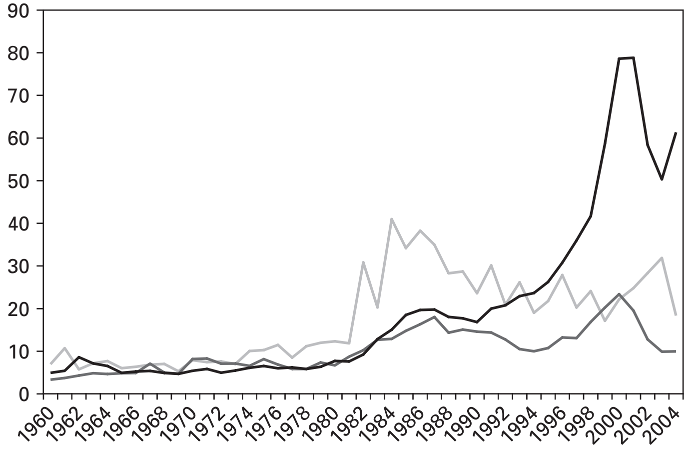

Figure 1.8
Profitability in IT-intensive industries (profit disparity between most profitable and least profitable companies in segment, as measured by interquartile range, 1960–2004). Source: Brynjolfsson, McAfee, Sorell, and Zhu 2009.

create value in the coming decade. We begin by discussing official measures of the size of the information economy and analyzing their limitations. We continue with the literature on IT, productivity, and economic growth. Next, we review the literature on business processes that enhance productivity. We look at attempts to quantify the value of these processes in the form of intangible organizational capital. We then examine the innovation literature in relation to technology, as well as other metrics of measuring the effect of technology the economy, such as consumer surplus. We conclude with a peek at emerging research.

Further Reading

Nicholas G. Carr, “IT Doesn’t Matter,” *Harvard Business Review* 81 (2003), no. 5: 41–49. This provocative article questions the strategic value of IT. The author sees IT near the end of its buildout and asserts that the biggest risk to IT is overspending.

Ray Kurzweil, *The Singularity Is Near: When Humans Transcend Biology* (Viking Penguin, 2005). This book predicts remarkable possibilities due to the accelerating nature of technological progress in the coming decades.

Andrew McAfee and Erik Brynjolfsson, “Investing in the IT That Makes a Competitive Difference,” *Harvard Business Review* 86 (2008), no. 7/8: 98–107. The authors find that the gap between leaders and laggards has grown significantly since 1995, especially in IT-intensive industries.