

Erik Brynjolfsson ■ Adam Saunders

# WIRED

FOR INNOVATION

How Information Technology Is Reshaping the Economy

*"Brynjolfsson and Saunders have written an important roadmap for future technology innovation. Anyone interested in the business and economics of information technology should read this book."*  
—Chris Anderson, Editor-in-Chief, *Wired*, author of *Free: The Future of a Radical Price*

---

## Wired for Innovation



---

# **Wired for Innovation**

How Information  
Technology Is  
Reshaping  
the Economy

Erik Brynjolfsson and  
Adam Saunders

The MIT Press  
Cambridge, Massachusetts  
London, England

---

© 2010 Massachusetts Institute of Technology

All rights reserved. No part of this book may be reproduced in any form by any electronic or mechanical means (including photocopying, recording, or information storage and retrieval) without permission in writing from the publisher.

For information about quantity discounts, email [specialsales@mitpress.mit.edu](mailto:specialsales@mitpress.mit.edu).

Set in Palatino. Printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data

Brynjolfsson, Erik.

Wired for innovation : how information technology is reshaping the economy / Erik Brynjolfsson and Adam Saunders.

p. cm.

Includes bibliographical references and index.

ISBN 978-0-262-01366-6 (hardcover : alk. paper)

1. Technological innovations—Economic aspects. I. Saunders, Adam.

II. Title.

HC79.T4.B79 2009

303.48'33—dc22

2009013165

10 9 8 7 6 5 4 3 2 1

---

## Contents

Acknowledgments vii

Introduction ix

- 1 Technology, Innovation, and Productivity  
in the Information Age 1**
- 2 Measuring the Information Economy 15**
- 3 IT's Contributions to Productivity and  
Economic Growth 41**
- 4 Business Practices That Enhance Productivity 61**
- 5 Organizational Capital 77**
- 6 Incentives for Innovation in the Information  
Economy 91**
- 7 Consumer Surplus 109**
- 8 Frontier Research Opportunities 117**

|              |     |
|--------------|-----|
| Notes        | 129 |
| Bibliography | 135 |
| Index        | 149 |

---

## Acknowledgments

The idea for this book originated in a request by Michael LoBue of the Institute for Innovation and Information Productivity for an accessible overview of research and open issues in the areas of IT innovation and productivity. With guidance and inspiration from Karen Sobel Lojeski at the IIIP, and through the IIIP's research sponsorship of the MIT Center for Digital Business, we were able to devote more than a year to studying the main research results in these areas and to producing a report that eventually became this book.

We are also grateful to the National Science Foundation, which provided partial support for Erik Brynjolfsson (grant IIS-0085725), and to the other research sponsors of the MIT Center for Digital Business, including BT, Cisco Systems, CSK, France Telecom, General Motors, Google, Hewlett-Packard, Hitachi, Liberty Mutual, McKinsey, Oracle, SAP, Suruga Bank, and the University of Lecce. We thank Paul Bethge and Jane Macdonald at the MIT



Press for their editing and for expert assistance with the publication process. Heekyung Kim, Andrea Meyer, Dana Meyer, Craig Samuel, and Irina Starikova commented on drafts of portions of the manuscript.

The ideas, examples, and concepts discussed in the book were inspired over a period of years by numerous stimulating conversations with our colleagues at MIT and in the broader academic and business communities. In particular, we'd like to thank Masahiro Aozono, Chris Beveridge, John Chambers, Robert Gordon, Lorin Hitt, Paul Hofmann, Dale Jorgenson, Henning Kagermann, David Verrill, and Taku Tamura for sharing insights and suggestions. Most of all, we would like to thank Martha Pavlakis and Galit Sarfaty for their steadfast support and encouragement.

---

## Introduction

The fundamentals of the world economy point to continued innovation in technology through the booms and busts of the financial markets and of business investment. Gordon Moore predicted in 1965 that the number of transistors that could be placed on a microchip would double every year. (Later he revised his prediction to every two years.) That prediction, which became known as Moore's Law, has held for four decades. Furthermore, businesses have not even exploited the full potential of existing technologies. We contend that even if all technological progress were to stop tomorrow, businesses could create decades' worth of IT-enabled organizational innovation using only today's technologies. Although some say that technology has matured and become commoditized in business, we see the technological "revolution" as just beginning. Our reading of the evidence suggests that the strategic value of technology to businesses is still increasing. For example, since the mid 1990s there has been a

dramatic widening in the disparity in profits between the leading and lagging firms in industries that use technology intensively (as opposed to *producing* technology). Non-IT-intensive industries have not seen a comparable widening of the performance gap—an indication that deployment of technology can be an important differentiator of firms' strategies and their degrees of success.

Despite decades of high growth in investment, official measures of information technology suggest that it still accounts for a relatively small share of the US economy. Though roughly half of all investment in equipment by US businesses is in information-processing equipment and software (as has been the case since the late 1990s), less than 2 percent of the economy is dedicated to producing hardware and software. When the computer systems design and related services industry is added, as well as information industries such as publishing, motion picture and sound recording, broadcasting and telecommunications, and information and data processing services, the total value added amounts to less than 7 percent of the economy. However, when it comes to innovation the story is quite different: every year in the period 1995–2007, between 50 percent and 75 percent of venture capital went into the funding of companies in the IT-production and information industries. We also see much greater turbulence and volatility in the information industries, reflecting the gale of creative destruction that inevitably accompanies disruptive innovation. Firms in those industries have a much higher ratio of intangible assets to

tangible ones. Because valuing intangibles is difficult, wealth for firms in these industries is often created or destroyed much more rapidly than for firms that are in the business of creating physical goods.

The literature on productivity points to a clear conclusion: information technology has been responsible, directly or indirectly, for most of the resurgence of productivity in the United States since 1995. Before 1995, decades of investment in information technology seemed to yield virtually no measurable overall productivity growth (an effect commonly referred to as the productivity paradox). After 1995, however, productivity increased from its long-term growth rate of 1.4 percent per year to an average of 2.6 percent per year until 2000. But information technology wasn't the sole cause of the increased growth. A significant body of research finds that the reason technology played a larger role in the acceleration of productivity in the United States than in other industrialized countries is that American firms adopted productivity-enhancing business practices along with their IT investments.

In the period 2001–2003, productivity growth accelerated to 3.6 percent per year, making that the best three-year period of productivity growth since 1963–1965. Whereas economists generally agree on the causes of the 1995–2000 productivity surge, there is less consensus in the literature about the 2001–2003 surge. We attribute it to the delayed effects of the huge investments in business processes that accompanied the large technology

investments of the late 1990s. The literature suggests that it can take several years for the full effects of technology investments on productivity to be realized because of the resultant redesign of work processes. An ominous implication of this analysis is that the sharp decline in IT investment growth rates in 2001–2003 may have been responsible for the decline in measured productivity growth 3–4 years later. In 2004–2006, productivity growth averaged only 1.3 percent. However, in 2007 and 2008 productivity growth nearly returned to its 1996–2000 rate, approximately 2.4 percent per year. If our hypothesis is correct, this may have been due in part to an increase in investment in IT that began in 2004.

The companies with the highest returns on their technology investments did more than just buy technology; they invested in organizational capital to become digital organizations. Productivity studies at both the firm level and the establishment (or plant) level during the period 1995–2008 reveal that the firms that saw high returns on their technology investments were the same firms that adopted certain productivity-enhancing business practices. The literature points to incentive systems, training, and decentralized decision making as some of the practices most complementary to technology. Moreover, the right *combinations* of these practices are much more important than any of the individual practices. Copying any one practice may not be very difficult for a firm, but duplicating a competitor's success requires replicating a

portfolio of interconnecting practices. Upsetting the balance in a company's particular combination of labor and capital investments, even slightly, can have large consequences for that company's output and productivity. As in a fine watch, the whole system may fail if even one small and seemingly unimportant piece is missing or flawed.

The unique combination of a firm's practices can be thought of as a kind of organizational capital. We are beginning to see in the literature the first attempts to value this intangible organizational capital, which could be worth trillions of dollars in the United States alone. Some researchers use financial markets, some attempt to add up spending on intangibles, and others use analysts' earning estimates to answer a basic question: How large are the annual investment and the total stock of intangible assets in the economy? For example, at the start of 2009 Google was worth approximately \$100 billion but had only \$5 billion in physical assets and about \$18 billion in cash, investments, and receivables (according to balance-sheet information and financial-market data for December 31, 2008; total financial value is the sum of market capitalization and liabilities). The other \$77 billion consisted of intangible assets that the market values but which are not directly observable on a balance sheet. Because the literature is not yet well developed, we expect to see more work in this area in the coming years. Various researchers have estimated that the annual investment in these intangibles

held by US businesses is at least \$1 trillion. A large portion of it does not show up in official measures of business investment. We see the attempt to quantify the value of these intangibles as a major research opportunity.

Producers of information goods face a major upheaval because of declining communication costs and because of the ease of replication and reproduction. Never before has it been so easy to make a perfect and nearly costless copy of an original information product. The music industry was one of the first to confront this transformation and is now going through a major restructuring. Many other industries will face similar disruption. An important task will be to improve the intellectual-property system to maximize total social welfare by encouraging innovation by producers while allowing as many people as possible to benefit from innovation at the lowest possible price.

Non-market transactions involving information goods generate significant value in the economy and provide a promising avenue for research. The total value that consumers get from Google or Yahoo searches is not counted in any official output statistics, and thus far no academic research has even attempted to quantify it. The lucrative business of keyword advertising pays for these searches. Internet users' demand for searches feeds the advertising market at search-engine sites and also drives visitors to publishers of other content. Highly targeted keyword advertising then feeds demand back to the advertisers'

sites. The two sides of the market are mutually reinforcing, which makes keyword searches and keyword advertising an example of *information complements*. The makers of information complements may subsidize one side of the market to promote growth of the other, as in the case of Adobe giving away its Reader software to enlarge the market for its PDF-writing Acrobat software. The cumulative value of the free or subsidized halves of these two-sided markets is potentially enormous, but today we have no measure for it. And there are other business models—exemplified by Wikipedia, YouTube, and weblogs—that generate enormous quantities of free goods and services, accounting for an increasing share of value, if not dollar output, in the world economy.

There are no official measures of the value of product variety or of new goods, but recent research indicates that this uncounted value to consumers is tremendous. In this book we examine an additional metric not included in government accounts as an important method of measuring the effect of technology on the economy. This metric is *consumer surplus*. Although the idea of consumer surplus is more than 150 years old, the use of this methodology to empirically value the introduction of entirely new goods or to value changes in the variety, quality, and timeliness of existing goods is relatively recent. However, the uncounted value from information goods is simply too large to ignore, and we need to do a better job of measuring it.



Aspects of the information economy that couldn't be measured by traditional methods can now be measured, analyzed, and managed. We used to think that the intangible nature of knowledge and information goods would make it virtually impossible to measure productivity, because of the difficulties inherent in measuring knowledge as an input and as an output. In an information economy, can we actually measure how much value came out versus how much data went in? The problem is not that we don't have enough data—it's that we have too much data and we need to make sense of it. To that end, we are excited by the results being generated from the first attempts to use email, instant messaging, and devices that record GPS data to construct social networks. These studies are being conducted at what we like to call the "micro-micro level," the first "micro" referring to the short time period and the second to the unit of analysis. With such data now being generated in the economy, we may be better able to measure productivity than ever before.

Managers and policy makers can better understand the relationships among information technology, productivity, and innovation by understanding the insights offered in recent literature on these topics. In this book, we summarize the best available economic research in such a way that it can help executives and policy makers to make effective decisions. We examine official measures of the

value and the productivity of technology, suggest alternative ways of measuring the economic value of technology, examine how technology may affect innovation, and discuss incentives for innovation in information goods. We conclude by recommending new ways to measure technological impacts and identifying frontier research opportunities.



---

## Wired for Innovation



---

# 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.<sup>1</sup> 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.<sup>2</sup> At the end of 2008, a dozen eggs cost about \$1.83,<sup>3</sup> a stamp was 42 cents, and the average price of a new car was \$28,350.<sup>4</sup> The Dow Jones was above 8,700, and gold was about \$884 an ounce.<sup>5</sup>

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.<sup>6</sup> 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.<sup>6</sup> 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,<sup>7</sup> 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,



---

sample content of Wired for Innovation: How Information Technology Is Reshaping the Economy  
(MIT Press)

- [download online The Scrambler's Dozen: The 12 Shots Every Golfer Needs to Score Like the Pros online](#)
- [click High Availability MySQL Cookbook book](#)
- **download online Probiotics For Dummies**
- [download online The Butcher's Apprentice: The Expert's Guide to Selecting, Preparing, and Cooking a World of Meat pdf](#)
- [read online Og Mandino's University of Success pdf, azw \(kindle\), epub](#)
  
- <http://hasanetmekci.com/ebooks/The-Scrambler-s-Dozen--The-12-Shots-Every-Golfer-Needs-to-Score-Like-the-Pros.pdf>
- <http://studystategically.com/freebooks/Wa-and-Ga.pdf>
- <http://aircon.servicessingaporecompany.com/?lib/Probiotics-For-Dummies.pdf>
- <http://www.gateaerospaceforum.com/?library/Blood-on-the-Verde-River--Byrnes-Family-Ranch--Book-3-.pdf>
- <http://serazard.com/lib/Learning-German-Through-Storytelling--Des-Spielers-Tod---A-Detective-Story-for-German-Language-Learners--For-Interm>