

Berndt, Ernst R.

**Article**  
**Productivity**

NBER Reporter Online

**Provided in Cooperation with:**

National Bureau of Economic Research (NBER), Cambridge, Mass.

*Suggested Citation:* Berndt, Ernst R. (2006) : Productivity, NBER Reporter Online, National Bureau of Economic Research (NBER), Cambridge, MA, Iss. Winter 2006/07, pp. 1-9

This Version is available at:

<https://hdl.handle.net/10419/61900>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

# NBER Reporter

NATIONAL BUREAU OF ECONOMIC RESEARCH

Reporter OnLine at: [www.nber.org/reporter](http://www.nber.org/reporter)

WINTER 2006/7

---

## Program Report

---

### IN THIS ISSUE

Program Report	
Productivity	1
Research Summaries	
Exchange Rate Regimes ...	10
Microeconomic Evidence on Contagion ...	13
Tax Policy Towards Energy ...	16
NBER Profiles	19
Conferences	21
NBER News	35
Program and Working Group Meetings	39
Bureau Books	63

## Productivity

**Ernst R. Berndt\***

It is now seven years since Zvi Griliches, the NBER's Productivity Program Director for its first twenty years, passed away in October 1999. Due in large part to Zvi's enormous intellectual legacy and the extraordinary efforts he expended in nurturing and mentoring young scholars, I am pleased to report that the NBER's Productivity Program today is vibrant and robust, and that its researchers are carrying on the tradition of examining sources and consequences of innovation and productivity growth, and in the process developing and empirically exploiting new datasets.

Efficiency and productivity are essential concepts in almost every economist's tool kit, and thus it is not surprising that many of the NBER's Productivity Program members are affiliated with other NBER Programs where these concepts are important as well, including Labor Studies, Industrial Organization, Corporate Finance, Economic Fluctuations and Growth, International Trade and Investment, Law and Economics, and Health Care. What distinguishes the Productivity Program's research focus from these other Programs at the NBER is its strong emphasis on the roles of research and development, patents, incentive systems, regulations, knowledge spillovers, technological progress, organizational form, and market structure in influencing the extent and nature of productivity growth and innovation. In addition, a disproportionate share of Productivity Program researchers have traditionally focused considerable attention on issues involving economic measurement, such as measures of inputs, outputs, prices, quality change, and multifactor productivity, a focus that reflects Zvi Griliches's enduring bequest.

### NBER Service Brings You New Data for Free

A new, **free** NBER email service gives you daily email links to all U.S. government data releases, including unemployment, trade, interest rates, GDP, etc. We keep track of your preferences and email you the requested links when they are released. To sign up for any or all of the government releases, visit [www.nber.org/releases](http://www.nber.org/releases) and register your choices. **IT'S — FREE!!**

---

\* Berndt directs the NBER's Productivity Program and is the Louis B. Seley Professor of Applied Economics at the MIT Sloan School of Management. In this article, the numbers in parentheses refer to NBER Working Papers.

The National Bureau of Economic Research is a private, nonprofit research organization founded in 1920 and devoted to objective quantitative analysis of the American economy. Its officers and board of directors are:

President and Chief Executive Officer — *Martin Feldstein*  
Vice President for Administration and Budget — *Susan Colligan*  
Controller — *Kelly Horak*

## BOARD OF DIRECTORS

Chairman — *Elizabeth E. Bailey*  
Vice Chairman — *John S. Clarkeson*  
Treasurer — *Robert Mednick*

## DIRECTORS AT LARGE

Peter Aldrich	Jessica P. Einhorn	John Lipsky
Elizabeth E. Bailey	Martin Feldstein	Laurence H. Meyer
John Herron Biggs	Jacob A. Frenkel	Michael H. Moskow
Andrew Brimmer	Judith M. Gueron	Alicia Munnell
John S. Clarkeson	Robert S. Hamada	Rudolph A. Oswald
Don R. Conlan	George Hatsopoulos	Robert T. Parry
Kathleen B. Cooper	Karen N. Horn	Marina v. N. Whitman
George Eads	Judy Lewent	Martin B. Zimmerman

## DIRECTORS BY UNIVERSITY APPOINTMENT

George Akerlof, <i>California, Berkeley</i>	Joel Mokyr, <i>Northwestern</i>
Jagdish W. Bhagwati, <i>Columbia</i>	Andrew Postlewaite, <i>Pennsylvania</i>
Michael J. Brennan, <i>California, Los Angeles</i>	Craig Swan, <i>Minnesota</i>
Glen G. Cain, <i>Wisconsin</i>	Uwe Reinhardt, <i>Princeton</i>
Ray C. Fair, <i>Yale</i>	Nathan Rosenberg, <i>Stanford</i>
Franklin Fisher, <i>MIT</i>	David B. Yoffie, <i>Harvard</i>
Saul H. Hymans, <i>Michigan</i>	Arnold Zellner, <i>Chicago</i>
Marjorie B. McElroy, <i>Duke</i>	

## DIRECTORS BY APPOINTMENT OF OTHER ORGANIZATIONS

Richard B. Berner, *National Association for Business Economics*  
Gail Fosler, *The Conference Board*  
Richard C. Green, *American Finance Association*  
Dr. Arthur Kennickell, *American Statistical Association*  
Thea Lee, *American Federation of Labor and Congress of Industrial Organizations*  
Robert Mednick, *American Institute of Certified Public Accountants*  
Angelo Melino, *Canadian Economics Association*  
Jeffrey M. Perloff, *American Agricultural Economics Association*  
John J. Siegfried, *American Economic Association*  
William W. Lewis, *Committee for Economic Development*  
Gavin Wright, *Economic History Association*

The NBER depends on funding from individuals, corporations, and private foundations to maintain its independence and its flexibility in choosing its research activities. Inquiries concerning contributions may be addressed to Martin Feldstein, President & CEO, NBER 1050 Massachusetts Avenue, Cambridge, MA 02138-5398. All contributions to the NBER are tax deductible.

The *Reporter* is issued for informational purposes and has not been reviewed by the Board of Directors of the NBER. It is not copyrighted and can be freely reproduced with appropriate attribution of source. Please provide the NBER's Public Information Department with copies of anything reproduced.

Requests for subscriptions, changes of address, and cancellations should be sent to *Reporter*, National Bureau of Economic Research, Inc., 1050 Massachusetts Avenue, Cambridge, MA 02138-5398. Please include the current mailing label.

Rather than attempting to summarize the full scope of program activity, much of which overlaps with other NBER programs, I will highlight in this report research in six broad areas, domains particularly prominent in Productivity Program research over the last four to five years. The sequence I follow will begin with research on individual inventors, followed by research on knowledge flows within and across firms and other institutions, on patents and intellectual property protection, on market structure, international trade and investment, and recent research on macroeconomics and productivity growth, particularly on the role of information and communications technology investments.

## Innovation at the Level of the Individual Inventor

Does technological progress, by expanding knowledge, place an increased educational burden on successive generations of innovators? Do today's innovators spend longer time in learning, and/or do they become more narrowly expert? Benjamin Jones (11359) shows that the age at which Nobel Prize winners and other great inventors produce great ideas has increased substantially over the twentieth century, specifically because of a large drop in productivity at young ages, and is closely related to an increasing age at completion of formal education. Focusing on more ordinary inventors, Jones (11360) shows that the age at first patent, teamwork, and specialization are all increasing over time. These papers suggest dramatic changes in the nature of innovation, with a decline in output by the very young and a ubiquitous move towards greater teamwork in the implementation of ideas. Related research by David Galenson (12185, 12058) on artistic innovation finds that artists who innovate early in their lives do so suddenly, while those who innovate late do so more gradually.

In a series of papers (9017, 10923, 11654) Kenneth Sokoloff and collaborators have used new micro data sets on patents, inventors, and patent assignment contracts in the United States beginning in the nineteenth century, and examined the changing division of labor between those who invented new technologies and those who exploited them commercially. Soon after the major patent reform of 1836, intermediaries — such as patent lawyers, agents, and agencies — emerged, facilitating transactions between buyers and sellers of patents. However, the move-

ment of inventors into firms — at least as employees — did not proceed very far before the 1920s, at which time inventive activity shifted to R and D laboratories housed in large corporations. In between, inventors developed long-term attachments with a firm in which the inventor was a principal, often by bringing investors with them. In related research comparing inventors in the United States and Britain between 1790 and 1930 (10966), Sokoloff and collaborators report that the relatively low patent application fee in the United States (about 2.5 percent of that in Britain until late in the nineteenth century), combined with the U.S. administrative examination rather than the British registration and prize procedures, resulted in U.S. patentees typically having relatively humbler origins than their British counterparts.<sup>1</sup>

Another research stream, more theoretical, focuses on incentives faced by academic researchers. It examines whether returns to university licensing divert faculty from basic to applied research and to less leisure as they age. Marie Thursby and co-authors (11197, 10758) also introduce complications from tenure and from the fact that academic researchers may earn license income and enhanced prestige both inside and outside the university. These authors conclude that it is far from obvious that licensing damages basic research and education.

While patent data has long been used in empirical research, information on the identity (name and location) of the inventor has seldom been employed, because of what Manuel Trajtenberg (12479) calls the “who is who” problem: the name of a given inventor may be spelled differently across his/her patents, and the same name may correspond to different inventors (the “John Smith” problem). To address this problem involving over four million patent records and 1.6 million inventors from across the world, Trajtenberg developed an elaborate computerized data mining methodology, resulting in detailed data on individuals’ patenting history, their employers, and co-inventors. He finds that 40 percent of patentees have more than one patent, and 70,000 have more than ten patents.

Managing R and D and innovation raises a number of issues regarding incentives. Beginning in the late 1980s, U.S. corporations increasingly linked compensation of central research personnel to the economic incentives of the corporation. Joshua Lerner and Julie Wulf (11944) examine the impact of the shifting compensation of the heads of corporate R and D. They report that among firms with centralized Rand D operations, more long-term incentives (for example, stock options and restricted stock) are associated with more heavily cited patents, with more patent filings, and with patents of greater generality. While they cannot distinguish between the roles of better project selection or better people selection, they interpret these findings as being consistent with the view that performance pay of corporate R and D heads is associated with more innovative firms.

## Knowledge Flows and Innovation Across Organizations

### *R and D*

Geographic proximity between academia and industry R and D laboratories has long been hypothesized to facilitate knowledge spillovers. Using program-level data on pharmaceutical drug discovery expenditures during the 1980s and 1990s and location-program-level data on relevant academic science, Jeffrey Furman, Margaret Kyle, Iain Cockburn, and Rebecca Henderson (12509) study how proximity of pharmaceutical research laboratories to universities and the laboratories of competing pharmaceutical companies influenced the number of patents generated by the laboratories. They find that “public” science — generated by universities, academic medical centers, and government laboratories — generated positive spillovers to geographically proximate private pharmaceutical research laboratories, but that no such spillovers occurred among private laboratories.<sup>2</sup> Focusing on an earlier phenomenon — the growth of U.S. industrial pharmaceutical laboratories between 1927 and 1946, Megan MacGarvie and Jeffrey Furman (11470) find that while the pres-

ence of nearby industrial facilities helped shape the direction of university research programs, there was a significant, positive and causal effect running from university research to the growth of pharmaceutical research laboratories in the first half of the twentieth century.

An obvious way in which knowledge flows can occur between academia and industry is via collaborative publications. Does the success of these collaborations depend on the research status of the faculty involved? Focusing initially on biotechnology, Lynne Zucker, Michael Darby, and Jeff Armstrong (8499) report that counts of collaborative publications by top research university faculty and firm employees are an empirically useful indicator of knowledge transfer leading to firm success, but that collaborative articles of the very top star academic scientists with firm employees predicted significantly more firm success than collaborations with other faculty. Based on a census of biotechnology firms that did and did not go public, Darby and Zucker (8954) find that among other factors, the strength of the firm’s science base (use of recombinant DNA technology, number of articles by star academic scientists as — or with — firm employees, number of biotech patents) reduced the time to initial public offering (IPO) and increased the expected proceeds raised from the IPO.

Zucker and Darby (9825, 11181) have extended this line of research to study nanoscale science and technology developments. An almost completed output of this research is NanoBank.org, a public digital library matching and linking individuals and organizations within and across the nanotechnology subsets of the Institute for Scientific Information (ISI) Web of Science, U.S. patent data, and firm financial records; the NBER will host a conference in 2007 where presented papers will use data drawn from the beta version of NanoBank. The concept of star scientist in numerous other areas of science and technology is examined empirically in Zucker and Darby (12172), in which they follow the 1981–2004 careers of 5,401 star scientists, as measured by ISIHighlyCited.com. They find that the number of stars in a U.S.



geographical region, or in one of the top-25 science and technology countries, generally has a significant and quantitatively large positive impact on the probability of firm entry in the same area of science and technology and that other measures of academic knowledge stocks have weaker and less consistent effects. Hence it is the stars themselves, more than their discoveries, which play a key role in the formation or transformation of high-tech industries. In terms of migration, Zucker and Darby report that in the United States stars become more concentrated over time, moving from areas with relatively few peers to those with many in their discipline. On the other hand, these authors also document the tendency of foreign-born American stars to return to their homeland when it develops sufficient strength in their area of science and technology.

Based on co-authorship counts among condensed matter physicists in the French “Centre National de la Recherche Scientifique”, Jacques Mairesse and Laure Turner (11172) report that co-authorship intensity is about 40 times higher within a given laboratory than across laboratories within the same city and about 100 times greater than in laboratories in other cities. Immediate proximity is therefore critical.

Jeffrey Furman and Scott Stern (12523) examine the impact of a different institution—biological resource centers (BRCs)—on the growth of the cumulative “knowledge stock” in molecular biology. BRCs authenticate, preserve, and offer independent access to biological research materials such as cells, cultures, and specimens, thereby reducing the marginal costs to researchers of building on prior research efforts. Employing a difference-in-differences estimator linking specific material deposits to journal articles, these researchers report not only a selection effect (disproportionately important materials are deposited and preserved in BRCs), but also that materials being deposited in BRCs result in a significant marginal “boost” in the diffusion of knowledge, as measured by journal article citations. The latter effect increases with time and varies with the economic and institutional conditions in which deposits occur.

Bibliometric research has long quantified knowledge flows and influence by measuring citations in published articles and patents. The Institute for Scientific Information collects data from the top 110 U.S. research universities in twelve main fields that cover nearly all of science. Based on 1981–99 data on 2.4 million papers and 18.8 million citations, James Adams, J. Roger Clemmons, and Paula E. Stephan (10875) compute citation probabilities as actual citations divided by potential citations. The mean citation probability within fields is on the order of  $10^{-5}$ , whereas cross-field citations are one tenth to one-hundredth as large, or  $10^{-6}$  to  $10^{-7}$ . Scientific influence is asymmetric within fields, and occurs primarily from top institutions to those less highly ranked. Using the same database, Adams (10640) reports that team size (as measured by the number of authors on an article) has increased by about 50 percent between 1981 and 1999, holding a number of other factors constant. Team size data are supplemented by measures of domestic and foreign institutional collaborations, capturing the geographic dispersion of team workers. The time-series evidence suggests that the trend toward larger and more dispersed teams accelerates at the start of the 1990s, which Adams conjectures may reflect sudden declines in the cost of collaboration attributable to improvements in telecommunications. Private universities and departments whose scientists have earned prestigious awards participate in larger teams, as do departments that have larger amounts of federal funding. Placement of former graduate students is a key determinant of institutional collaborations, especially collaborations with firms and foreign scientific institutions. Adams finds that scientific influence increases with team size and institutional collaborations. He interprets increased team size as reflecting an increase in the division of labor, and concludes that scientific productivity increases with the scientific division of labor.

Since relatively little academic research is patented, and only a fraction of the patents are ever licensed, Lee Branstetter and Yoshiaki Ogura (11561) examine the uni-

verse of industry patent citations from a set of California-based research universities, and assess changes over time in the propensity of U.S. industry patents to cite these papers, controlling for a variety of other factors. Branstetter and Ogura find patterns in their data consistent with the notion that there has been an increase in knowledge spillovers from academic science to commercial invention, but that this increase is highly concentrated in a small number of technical fields.

### *Diffusion of Superior Management Practices within Multinational Firms*

While patent and professional journal citations are channels through which knowledge flows can be observed and quantified, there are many other ways in which knowledge transfer can occur, particularly within firms. NBER researchers are beginning to search for evidence of knowledge transfer within multinational firms. Productivity growth in sectors intensively using information technologies (IT) has been greater in the United States than in Europe since 1995. Using U.K. panel data on U.S. and non-U.S. multinational-owned establishments, Nick Bloom, Raffaella Sadun, and John VanReenen find that U.S. owned establishments have a stronger relationship between IT and productivity capital than either non-U.S. multinationals or domestic establishments.<sup>3</sup> This finding is robust to inclusion of fixed effects and holds when a sample of establishments taken over by U.S. multinationals is examined. Moreover, this U.S. multinational effect of IT is particularly strong in sectors such as retail and wholesale that use IT intensively; notably, as discussed below, it is these very same industries that account for much of the U.S.-European productivity growth differential since the mid-1990s. In related research, Lee Branstetter (8015) finds that Japanese multinational firms’ network of affiliates in the United States are a significant channel of knowledge spillovers from Japan to the United States and vice-versa. These results are consistent with those of Wolfgang Keller and Stephen Yeaple (9504) who, using firm-level Compustat data and detailed unpublished data from the U.S. Bureau

of Economic Analysis on the industry classification of foreign-owned affiliates, find evidence for major FDI spillovers from affiliates of foreign-owned firms in the United States to U.S.-owned firms between 1987 and 1996; such spillovers explain about 11 percent of the U.S. manufacturing multifactor productivity growth during this time period.

## Patents, R&D, Innovation and Firms' Valuations

While the existence of intellectual property (IP) protection through patents has long been thought to provide positive incentives for R and D and innovation, a growing “anti-commons” perspective highlights the negative role of patents in facilitating knowledge accumulation relative to publication in professional journals. Fiona Murray and Scott Stern (11465) note that a given discovery may contribute both to scientific research (journal publication) and to useful commercial applications (patents); they examine patent-paper pairs in biotechnology, exploiting the fact that patents are granted with a substantial lag, often years after the knowledge is initially disclosed through journal publication. Diffusion of citations occurs in both the pre-grant period and after formal IP rights are granted. Relative to the expected citation pattern for publications with a given quality level, the “anti-commons” hypothesis predicts that the citation rate to a scientific publication should fall after formal IP rights associated with that publication are granted.

Using a difference-in-differences estimator for 169 patent-paper pairs (and including a control group of other publications from the same prestigious *Nature* journal for which no patent was granted), Murray and Stern find evidence for a modest anti-commons effect, with the post-patent grant decline in citations of about 10–20 percent. This decline becomes more pronounced with the number of years elapsed since the date of patent grant, and is particularly salient for articles written by researchers with public sector affiliations. Hence, while this evidence suggests that formal IP rights do not seem to have a devastating impact on subsequent sci-

entific research, the increased use of formal IP appears to be significantly shaping the structure, conduct, and performance of both university and industry researchers. Additional implications of IP protection for the generation and accumulation of scientific and commercial knowledge are considered by Murray and Stern in another NBER publication.<sup>4</sup> Related research by Bronwyn Hall (7643) and Hall and Alfonso Gambardella (11120) has centered on IP issues arising from university-industry interactions, and documents the tensions that have arisen.

Patents on software and business methods have become highly controversial, with critics claiming that patents stifle innovation by holding up the development of technology that builds on patented prior art and by swamping inventors with patent-infringement suits; see, for example, Josh Lerner and Feng Zhu (11168). Iain Cockburn and Megan MacGarvie (12563) examine the effects of software patents on entry and exit in narrowly defined classes of software products, using a dataset with comprehensive coverage of both mature public firms and small privately held firms between 1994 and 2004; they find both stifling and stimulating effects of patents on entry. All else equal, greater numbers of patents held by incumbents have a negative impact on entry rates into narrowly defined software product markets, while greater numbers of patents held by entrants increase the rate of entry and decrease the rate of exit, all else equal. Related research by Lerner (7918, 10223) examines the impact of a notable judicial decision involving State Street Bank on financial patenting behavior.

In Hall and MacGarvie (12195), the authors examine valuation effects of software patenting. Major changes in software patentability occurred in the U.S. Patent and Trademark Office in 1995. After 1995, software patents became more valuable than ordinary patents, but Hall and MacGarvie find that if the patents are held by hardware firms, then it does not matter whether these patents are cited. That is, the “importance” of software patents held by non-software firms has no impact on firms' valuations, although

their existence does. The authors also report that the extension of patentability to software was initially negative for software firms, especially for those producing application software or services.

The worldwide expansion of patenting activity by firms in many sectors has led to an increase in the uncertainty and costs associated with enforcing one's own patents and defending against the patents of others. Building on earlier work by Hall and Rosemarie Ziedonis (7062) that found that increases in patenting in the semiconductor industry were driven largely by a need to amass large defensive patent portfolios because of technological complexity and threat of holdup, Hall (10605) reports that patent growth in the United States since 1984 has taken place in all technologies, but not in all industries, being concentrated in the electrical, electronics, computing, and scientific instruments industries. Although the 5–8 percent annual growth may reflect in part accelerated innovation, this growth has seriously affected patent offices worldwide and has led to increasing concern over patent quality and timeliness of issuance. Research by Cockburn, Sam Kortum, and Scott Stern (8980) on the relationship between poor examination and subsequent costly patent litigation, however, was unable to uncover any relationship. Hall, Stuart Graham, Dietmar Harhoff, and David Mowery (8807, 9731) investigate the workings and outcomes of the patent opposition system, a procedure not available in the United States, but used in Europe, and assess how such a system might function in the United States. In related research, Lerner (7477, 7478 and 8977) examines patent office practice, patent protection, and innovation over a 150-year time period, for a number of countries.<sup>5</sup>

David Popp, Ted Juhl, and Daniel Johnson (9518) examine grant lags for U.S. patent applications and find considerable differences across technology. Patents in biotechnology and software experience the longest delays, but for different reasons: biotechnology patents are most likely to go through several revisions during the examination process, reflecting their complexity, whereas

software patents do not undergo revisions more frequently, but rather sit in the queue longer. Adding more software examiners therefore might reduce grant lags, but lags in biotechnology approvals are unlikely to be greatly affected by increasing the number of biotechnology examiners.

The energy sector has been the focus of R and D by both government and industry. Around 1981, according to Popp (11415), U.S. government R and D shifted its focus from applied (for example, synthetic fuels) to more basic in nature. Using patent citations as a measure of energy R and D quality, Popp finds that the likelihood of a patent receiving a citation from a future patent in the same field has fallen over time, which he interprets as evidence of diminishing returns to R and D over time. Distinguishing government patents from before and after the 1981 change in focus, Popp reports that government patents filed after 1981 are more likely to be cited, and moreover, that descendants of these patents—private patents that cite these government patents—are 30 percent more likely to be cited by subsequent patents. Popp concludes that government and industry R and D have distinct roles to play in the innovation process.

A lengthy NBER collaboration among Bronwyn Hall, Adam Jaffe, and Manuel Trajtenberg has put into the public domain a database that has been used subsequently by many researchers (the NBER's Patent Citation Data File). An early contribution by these authors (7741) investigated whether the citations received by U.S. firm's patents conveyed information about their private stock market valuation; they found that patent citations were more informative about value than the patents themselves, with interesting variation across sectors.

Hall has also pursued the closely related area of the market value of R and D spending, both for U.S. firms (with Jaffe and Trajtenberg in 7741) and for firms in a number of major European countries (with Raffaele Oriani in 10408). While R and D undertaken in France, the United States, and Germany is valued similarly, the value of R and D performed in the United Kingdom and Italy is substan-

tially higher, which the authors interpret as suggesting that there may be underinvestment in innovative activities in these two countries.

Conventional accounting practices traditionally exclude from gross domestic product investments in intangible capital, such as R and D, patents, brand equity and advertising, and human competency. Carol Corrado, Charles Hulten, and Daniel Sichel estimate that this practice implicitly ignores approximately \$1 trillion of the output of the non-farm business sector in the United States by the late 1990s, an amount approximately equal to the amount of investment spending on tangible capital goods, and about 10 percent of gross domestic product.<sup>6</sup> The same authors (11948) extend the time dimension and carry out a formal sources-of-growth analysis. Among the more important findings, the authors report that intangible inputs have grown more rapidly than other inputs over the last four decades, that most of this expansion is not attributable to the growth in scientific R and D, but instead reflects growth in non-traditional intangibles such as non-scientific R and D, and management and human competencies. When intangibles are included in the analysis, capital deepening replaces multifactor productivity as the principal source of economic growth after 1995; notably, including intangibles has little effect on the acceleration of multifactor productivity in the mid-1990s. These, and a number of related issues involving the construction of R and D satellite accounts as a supplement to the National Income and Product Accounts, are considered by Barbara Fraumeni and Sumiye Okubo.<sup>7</sup>

### **Innovation, Organizational Form, and Market Structure**

Causality between innovation and market structure generally has been viewed as being bidirectional, reflecting both Schumpeterian and network externality influences. In (9269), Philippe Aghion, Nick Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt develop a theoretical framework and then demonstrate empirically with U.K. firm data

that the relationship between innovation and competition appears to be an inverted U-shape. At low levels of competition, increases in competition spur on more innovation, but at higher levels of innovation, additional competition appears eventually to reduce any further innovation. In their U.K. dataset, most industries were on the increasing part of the slope, consistent with earlier findings that the net impact of competition is to increase innovation. They conclude that more competition is, on average, likely to boost competition, but that at extremely high levels of competition there may be a trade-off between the positive efficiency and pricing effects of additional competition with the potentially negative innovation impacts. In contrast, arguing that growth in any country at any time is typically uneven and instead concentrated in a few firms in a few industries achieving metamorphic technological progress as a result of highly uncertain but breakthrough innovations, Darby and Zucker (12094) argue (à la Schumpeter) that despite lagged diffusion, consumers' welfare is greater with dominant firms in concentrated industries because of enhanced innovation.

Bee Yan Aw, Sukkyun Chung, and Mark Roberts (8629) compare linkages among firm-level productivity, R and D investment, and survival for firms in the same industry in Korea and in Taiwan. They find that Taiwanese industries are characterized by less concentrated market structure, more producer turnover, a smaller percentage of plants operating at low productivity levels, and smaller productivity differentials between surviving and failing producers. They interpret these results as reflecting strong competitive pressures in Taiwan that lead to market selection based on productivity differences, and the presence of impediments to entry or exit that insulate low productivity producers in Korea.

In a different line of research, Chad Syverson (10501, 12231) examines how demand-side product substitutability affects industry structure and performance in the U.S. ready-mixed concrete industry, an industry where product substitutability is determined largely by the density of



concrete producers in the market. With high density, consumers' ability to substitute implies that relatively inefficient producers are unable to be profitable, resulting in higher minimum and average productivity levels, less productivity dispersion, and lower prices because of spatial competition. Transport costs play a very critical role in the ready-made concrete industry, so in additional work (10049) Syverson explores the substitutability-productivity link across a number of different industries. He finds that product substitutability measured in several ways—transport costs, physical product differentiation, and advertising-driven brand differentiation—is negatively related to within-industry productivity dispersion and positively related to industries' median productivity levels. In related work using plant-specific physical output and unit price measures, Lucia Foster, John Haltiwanger, and Syverson (11555) also report that physical productivity is inversely correlated with plant-level prices.

In yet another strand of literature, as an alternative framework to “racing” models that assume R and D competition between a potential entrant and an incumbent, Joshua Gans, David Hsu, and Scott Stern (7851) endogenize the choice of product market competition versus cooperation with established firms (via licensing, alliances, or acquisition). They hypothesize that the relative returns to cooperation increase with control over IP rights, low transaction costs, and greater sunk costs associated with product market entry. They find empirical support for all three factors in determining commercialization strategies, and conclude that the pro-competitive impact of start-up innovation—the “gale of creative destruction”—depends on imperfections in the market for ideas. More generally, this research strand establishes that the industrial organization consequences of start-ups are endogenous to the commercialization environment, including factors such as the strength of IP rights, the availability of venture capital, and sunk costs. Josh Lerner and various co-authors consider related research on issues involving R and D and marketing-performance impacts from various forms of alliances and financing for a variety of prod-

uct technologies (8251, 9175, 9680, 9816, 10165, 10956, 11136, and 11292).

Interest in factors affecting an organization's ability to innovate has evolved to the development of a new form of survey, called innovation surveys, in a number of European countries. Based on a common core questionnaire, the country surveys assemble information on innovators and non-innovators, where “innovators” are defined as firms that have introduced a new product or process over the last three years, “new” is defined as substantially improved or completely new, and a distinction is made between products new to the firm but not necessarily new to the market and products new to the firm and the market. Jacques Mairesse, along with co-authors Pierre Mohnen, Elizabeth Kremp, and others (8644, 10237, 10897, 12280, and 12320), has developed a three-tier framework that examines firms' R and D investment function, a knowledge function with R and D as an input, and an innovation output function. They use this framework to account for differences across firms, industries, and countries in the propensity for “innovativity”, analogous to multifactor productivity in traditional growth accounting analyses. They interpret innovativity as reflecting the ability to transform R and D and other innovation factors into innovation output, along with other unobserved and unmeasured factors.

NBER researchers also have examined the relationship between market structure and diffusion. Envisaging takeovers as playing roles similar to the entry and exit of firms, Boyan Jovanovic and Peter Rousseau (9279) argue that from 1890–1930, when electricity and the internal combustion engine spread through the U.S. economy, and more recently from 1971–2001 (the “Information Age”), takeovers played a major role in accelerating the diffusion of new technologies.

## **Productivity and International Trade**

NBER Productivity researchers have contributed extensively to literatures explaining bilateral patterns of trade between countries, and quantifying gains

from trade. An early contribution was by Jonathan Eaton and Sam Kortum (6253), for which they were awarded the Frisch Medal in 2004. In this paper, Eaton and Kortum modeled observed aggregate trade volumes as a tug of war between technology differences that led to more trade and trade costs leading to less trade. In subsequent research with Andrew Bernard and J. Bradford Jensen, Eaton and Kortum (7688) examined U.S. plant-level export data, and empirically examined facts about how few firms export, how small a fraction of exporters are, and how much greater is their productivity. In Eaton, Kortum, and Francis Kramarz (10344), this framework is extended to study the detailed export behavior of French firms, while in Johannes Van Biesebroeck (10020) related research focuses on the effects of exports on the productivity performance of sub-Saharan manufacturing plants. Eaton and Kortum (12385) summarize this line of research linking innovation, diffusion, and international trade.

A most interesting case analysis of the productivity and price impacts of entry by a large retailer is the study by Beata Javorcik, Wolfgang Keller, and James Tybout (12457), based on interviews of Mexican firms, on the response of the Mexican soaps, detergents, and surfactant (SDS) producers to entry by Wal-Mart. The authors argue that the most fundamental effect of the North American Free Trade Agreement and the General Agreements on Tariff and Trade on Mexico's SDS industry was to induce Wal-Mart to enter Mexico. Once there, Wal-Mex fundamentally changed the retail sector, forcing SDS firms to cut their prices and/or innovate. Those unable to respond to this new environment tended to lose market share and, in some cases, to disappear altogether. As a result, many Mexican producers achieved impressive efficiency gains, both from labor shedding and innovation, which in turn was fueled by innovative input suppliers and by multinationals bringing new products and processes into Mexico.

Advocates of stronger IP protection in developing countries have suggested that stronger IP rights would induce mul-



tionals to transfer more and better technology to IPR-reforming countries, and to do so at a more rapid rate than would obtain in a weak IPR environment, thereby benefiting the IPR-reforming countries. Using Bureau of Economic Analysis data on foreign direct investment, Lee Branstetter, Raymond Fisman, and Fritz Foley (11516) report that recent IPR reforms have in fact resulted in a quantitatively significant increase in technology transfer by U.S.-based multinational parents to their affiliates in IPR-reforming countries. Bee Yan Aw, Mark Roberts, and Tor Winston (11174) focus on the complementary role of export market participation and R and D investment as a source of knowledge acquisition and productivity growth for Taiwanese electronics producers, based on “learning by exporting”. They find that firms that export but do not invest in R and D have significantly higher future productivity than firms that do not engage in either activity, but that firms that both export and perform their own R and D have the highest average future productivity levels among all groups. This pattern is consistent with the hypothesis that R and D and exports are complementary activities contributing to firm-level productivity growth.

More generally, the very substantial literature appearing between 1993 and 2003 on international technology diffusion via the mechanisms of international trade and foreign direct investment, as well as the geographical localization and productivity growth impacts of this diffusion, is identified and summarized in Wolfgang Keller (8573).

### **Aggregate Productivity Growth and the Role of Information Technology Investments**

Two questions that have motivated macroeconomic productivity over the last decade have been what caused the revival in U.S. productivity growth after 1995 and its further jump in 2001–4, and why did productivity growth in Europe slow down just as that in the United States was accelerating? NBER researcher Robert J.

Gordon has addressed both of these issues in three papers. Separating actual productivity growth from its underlying trend, Gordon calculates trend acceleration from around 1.5 percent annually in the early 1990s to over 3 percent per year in 2002–3.<sup>8</sup> Actual growth was even faster in 2002–3, reflecting a standard cyclical phenomenon he calls the “early recovery bubble”, in which during the early stage of an economic recovery, firms persist in cutting costs and shedding labor, reacting to the previous recession even as output begins to recover. Gordon attributes the labor productivity “explosion” in the early part of this decade primarily to unusually deep corporate cost cutting resulting from the sharp drop in profits and stock prices in 2000–2, from the aftermath of the accounting scandals, and the increasing reliance of executive pay on stock options. An alternative hypothesis, offered by Susanto Basu, John Fernald, Nicholas Oulton, and Sylaja Srinivasan (10010) is that much of the productivity payoff of the heavy IT investments of the late 1990s were delayed because of lags in adopting software and business practices to the rapid improvements in IT hardware capability of the previous decade.

Gordon and Ian Dew-Becker (11842) examine the consequences of this labor productivity growth on nominal wage growth and inflation. While increased productivity growth since 1995 has moderated inflation, Gordon and Dew-Becker obtain the provocative finding that over the entire 1966–2001 time period, only the top 10 percent of the income distribution achieved gains in wage and salary income equal to the growth rate of labor productivity, while the bottom 90 percent fell behind. The authors attribute this increased skewness of the income distribution to disproportionate income gains at the top—primarily of entertainment and sports “superstars” and to chief executive officers of large corporations—along with downward pressure for most workers coming from shrinking unionization, rising imports, and job competition from immigration.

Turning to U.S.-European comparisons, Gordon (10661) documents that after 1995 the growth rate of productivity

in western Europe (the EU-15 countries) slowed down about as much as it accelerated in the United States, implying that half of the divergence was attributable to better American performance and half to worse European performance. He then argues that since Europe uses much of the same IT software and hardware as does the United States, it is implausible to cite IT investment as playing an important role on either side of the Atlantic (recall my earlier discussion of different productivity in U.S.- and European-owned multinational plants in Europe, by Bloom and co-authors). Rather, he attributes the difference to variations in specific industries, most notably wholesale and retail trade, and in finance. Regarding retailing, the key development that Gordon cites is the development of the “big box” format, led by Wal-Mart, Home Depot, Best Buy, and others. In turn, the success of this formula relies on largely deregulated use of land in the United States, where it is relatively easy to build a Wal-Mart at expressway interchanges. Gordon notes that much of European retailing still takes place in small stores in central cities with little physical space to take advantage of modern technology.

A related but different set of issues are examined by William Nordhaus (11354), who focuses on the productivity rebound in the last decade in U.S. manufacturing industries, where manufacturing employment has declined sharply. He finds that the productivity rebound since 1995 has been widespread, with approximately 40 percent of it occurring in “New Economy” industries. Interestingly, Nordhaus finds that the relevant productivity-employment elasticities indicate that more rapid productivity growth leads to increased, rather than decreased, employment in manufacturing. This leads him to conclude that productivity growth is not to be feared, at least not in U.S. manufacturing, where the largest recent employment declines have occurred.

Focusing on an earlier era, and using pooled cross-section, time series data for 44 industries over the decades of the 1960s, 1970s, and 1980s in the United States, Edward Wolff (8743) finds no econometric evidence that computer

investment is positively linked to multifactor (not labor) productivity growth. However, computerization is positively associated with occupational restructuring and changes in the composition of intermediate inputs and capital coefficients. He also finds very modest evidence that the growth of worker skills is positively related to industry productivity growth. In other research in which he incorporates the age structure of capital into the measurement of productivity, Wolff (1978) finds that once variations in the vintage composition of capital are taken into account and capital stock is measured in efficiency units, multifactor productivity growth is smoothed considerably, particularly during the 1970s slowdown, relative to ignoring the effects of changing vintage capital composition.

## Concluding Remarks

This summary of recent contributions by NBER Productivity Program researchers documents that the program continues to be wide-ranging, vibrant, and robust. It is also worth noting that while lengthy, this summary is incomplete in that I have omitted detailed discussion of much Productivity Program research that focuses on measurement issues, such as that involving price measurement incorporating quality changes, standard errors for price indexes, alternative measures of innovation, measuring output in diffi-

cult sectors such as finance and banking, and computing consumers' valuations of new goods. I also have omitted discussion of research on the productivity impacts of various federal and state regulatory policies, including environmental regulations in the context of climate change. Discussion of these issues is deferred to a subsequent issue of the *NBER Reporter*.

---

<sup>1</sup> B. Zorina Khan and K. L. Sokoloff, "Of Patents and Prizes: Great Inventors and the Evolution of Useful Knowledge in Britain and the United States, 1750–1930", Department of Economics, University of California-Los Angeles. Available from [sokoloff@ucla.edu](mailto:sokoloff@ucla.edu).

<sup>2</sup> A less technical summary of this research is given in M. Kyle, "Does Locale Affect R&D Activity? The Case of Pharmaceuticals", Federal Reserve Bank of San Francisco Economic Letter, Nov. 13, 2004.

<sup>3</sup> N. Bloom, R. Sadun, and J. VanReenen, "It Ain't What You Do but the Way That You Do I.T.: Investigating the Productivity Miracle Using Multinationals", presented at 2005 NBER Summer Institute Productivity Program. Available from [nbloom@stanford.edu](mailto:nbloom@stanford.edu).

<sup>4</sup> F. Murray and S. Stern, "When Ideas are Not Free: The Impact of Patents on Scientific Research," in A. Jaffe, J. Lerner, and S. Stern, eds., *Innovation Policy and the Economy*, Vol. 7, MIT Press for the National Bureau of Economic Research,

forthcoming.

<sup>5</sup> An overview of patent policy developments and their consequences in the last two decades in the United States is found in A. Jaffe and J. Lerner, *Innovation and its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What To Do About It*, Princeton: Princeton University Press, 2005.

<sup>6</sup> C. Corrado, C. Hulten, and D. Sichel, "Measuring Capital and Technology: An Expanded Framework", in C. Corrado, J. Haltiwanger, and D. Sichel, eds., *Measuring Capital in the New Economy*, University of Chicago Press for the National Bureau of Economic Research, Conference on Research in Income and Wealth, 2005, pp. 11–41.

<sup>7</sup> B. M. Fraumeni and S. Okubo, "R&D in the National Income and Product Accounts: A First Look at Its Effect on GDP", in C. Corrado, J. Haltiwanger, and D. Sichel, eds., *Measuring Capital in the New Economy*, University of Chicago Press for the National Bureau of Economic Research, Conference on Research in Income and Wealth, 2005, pp. 275–316.

<sup>8</sup> R. J. Gordon, "Exploding Productivity Growth: Context, Causes, and Implications", *Brookings Papers on Economic Activity*, Vol. 34 (2003, No. 2), pp. 207–98. Available as NBER Reprint No. 2300.