Innovation and Productivity Growth

T.W. Schultz Lecture

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"The puzzle confronting economists has been that the rate of growth of output that was being observed has been much larger than the rate of increase in the principal resources that were being measured. It is now clear that this puzzle is of our own making because we have been using measures of capital and labor which had been refined and narrowed in ways that excluded many of the improvements that have been made in the quality of these resources." Theodore W. Schultz (1962).

The computer equipment manufacturing industry comprised only 0.3 percent of U.S. value added from 1960–2007, but generated 2.7 percent of economic growth and 25 percent of productivity growth. By comparison agriculture accounted for 1.8 percent of U.S. value added, but only 1.0 percent of economic growth during this period. This reflects the fact that agriculture has grown more slowly than the U.S. economy, while the computer industry has grown thirteen times as fast. However, agriculture accounted for fifteen percent of U.S. productivity growth, indicating a very significant role for agricultural innovation.

The purpose of this paper is to assess the role of innovation in U.S. economic growth during the period 1960–2007. Productivity growth is the key economic indicator of innovation. Despite the importance of innovation in industries like computers and agriculture, this innovation accounts for less than twelve percent of U.S. growth. The great bulk of economic growth in the U.S. is due to the replication of existing technologies through investment and expansion of the labor force. Although innovation contributes only a modest portion of economic growth, this contribution is vital to gains in the U.S. standard of living.

The predominant role of replication of existing technologies in U.S. economic growth is crucial to the formulation of economic policy. As the U.S. economy recovers from the Great Recession of 2007–2009, economic policy must focus on maintaining the growth of employment and reviving investment. Policies that concentrate on enhancing the rate of innovation will have a relatively modest impact over the intermediate term of 5–10 years. However, the long-run growth rate of the economy depends critically on the performance of a relatively small number of sectors, such as agriculture and computers, where innovation takes place.

This paper begins with a brief history of productivity measurement. The traditional approach of Simon Kuznets (1971) and Robert Solow (1970), has been superseded by the new framework presented in Paul Schreyer's OECD (2001) manual, *Measuring Productivity*. The focus of productivity measurement has shifted from the economy as a whole to individual industries like agriculture and computers. The OECD productivity manual has established international standards for economy-wide and industry-level productivity measurement.

The OECD standards for productivity measurement are based on the production accounts constructed by Jorgenson, Frank Gollop, and Barbara Fraumeni (1987). These accounts have been updated and revised to incorporate investments in information technology hardware and software by Jorgenson, Mun Ho, and Kevin Stiroh (2005). The EU (European Union) KLEMS (capital, labor, energy, materials, and services) study, described by Mary O'Mahony and Marcel Timmer (2009), was completed on June 30, 2008. This landmark study presents productivity measurements for 25 of the 27 EU members, as well as Australia, Canada, Japan, and Korea, and data for the U.S. based on those of Jorgenson, Ho, and Stiroh (2005). Current data for the participating countries are available at the EU KLEMS website: http://www.euklems.net/.

The hallmark of the new framework for productivity measurement is the concept of capital services, including the services

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provided by IT equipment and software. Modern information technology is based on semiconductor technology used in computers and telecommunications equipment. The economics of information technology begins with the staggering rates of decline in the prices of IT equipment used for storage of information and computing. The "killer application" of the new framework for productivity measurement is the impact of IT investment summarized below. The final section sums up the paper.

The New Framework for Productivity Measurement

A detailed survey of recent research on sources of economic growth is given in my 2005 paper, "Accounting for Growth in the Information Age". A survey of earlier research is given in my 1990 article, "Productivity and Economic Growth", presented at the Jubilee of the Conference on Research in Income and Wealth, commemorating the fiftieth anniversary of the founding of the Conference by Kuznets. Additional surveys are provided by Zvi Griliches' (2000) posthumous book, *R& D, Education, and Productivity*, and Charles Hulten's (2001) article, "Total Factor Productivity: A Short Biography".

The most serious challenge to the traditional approach to productivity measurement of Kuznets (1971) and Solow (1970) was mounted by my 1967 paper with Griliches, "The Explanation of Productivity Change". Griliches and I departed radically from the measurement conventions of the traditional approach. We replaced NNP with GNP as a measure of output and introduced constant quality indexes for both capital and labor inputs. Jorgenson (2002) refers to this as the *production theory* approach to measurement.

The key idea underlying our *constant quality index of labor input* was to distinguish among different types of labor inputs. We combined hours worked for each type into a constant quality index of labor input, using labor compensation per hour as weights in the index number methodology Griliches (1960) had developed for U.S. agriculture. This considerably broadened the concept of substitution employed by Solow (1957).

While Solow modeled substitution between capital and labor inputs, Griliches and I extended the concept of substitution to include different types of labor inputs as well. This altered, irrevocably, the allocation of economic growth between substitution and technical change. Constant quality indexes of labor input are discussed detail by Jorgenson, Gollop, and Fraumeni (1987, Chapters 3 and 8, pp. 69–108 and 261–300), and Jorgenson, Ho, and Stiroh (2005, Chapter 6, pp. 201–290).

Griliches and I introduced a *constant quality index of capital input* by distinguishing among different types of capital inputs. To combine these capital inputs into a constant quality index, we identified prices of the inputs with rental prices, rather than the asset prices used in measuring capital stock used by Solow and Kuznets. This also broadened the concept of substitution and further altered the allocation of economic growth between substitution and technical change.

Griliches and I employed a model of capital as a factor of production I had introduced in my 1963 article, "Capital Theory and Investment Behavior". This made it possible to incorporate differences among depreciation rates on different assets, as well as variations in returns due to the tax treatment of different types of capital income, into the rental prices. Constant quality indexes of capital input are presented by Jorgenson, Fraumeni, and Gollop (1987, Chapters 4 and 8, pp. 109–140 and 267–300), and by Jorgenson, Ho, and Stiroh (2005, Chapter 5, pp. 147–200).

Finally, Griliches and I replaced the aggregate production function employed by Kuznets and Solow with the *production possibility frontier* introduced in my 1966 paper, "The Embodiment Hypothesis". This allowed for joint production of consumption and investment goods from capital and labor services. I used this approach to generalize Solow's (1960) concept of embodied technical change, showing that productivity growth could be interpreted, equivalently, as "embodied" in investment or "disembodied". My 1967 paper with Griliches removed this indeterminacy by introducing constant quality price indexes for investment goods. As a natural extension of Solow's (1956) one-sector neo-classical model of economic growth, his 1960 model of embodiment had only a single output and did not allow for the introduction of a separate price index for investment goods.

Nicholas Oulton (2007) demonstrates that Solow's model of embodied technical change is a special case of the model I had proposed in 1966. He also compares the empirical results of Solow's one-sector model and a two-sector model with outputs of consumption and investment goods. Jeremy Greenwood and Per Krussell (2007) employ Solow's one-sector model, replacing constant quality price indexes for investment goods with "investment-specific" or embodied technical change. The deflator for the single output, consumption, is used to deflate investment, conflicting with a requirement of the systems of national accounts discussed below, namely, separate deflators for consumption and investment.

Griliches and I showed that changes in the quality of capital and labor inputs and the quality of investment goods explained most of the Solow residual. We estimated that capital and labor inputs accounted for eighty-five percent of growth during the period 1945–1965, while only fifteen percent could be attributed to productivity growth. Changes in labor quality explained thirteen percent of growth, while changes in capital quality another eleven percent.[1] Improvements in the quality of investment goods enhanced the growth of both investment goods output and capital input, but the net contribution was only two percent of growth. In short, we had successfully quantified the insights of Schultz (1962), quoted at the beginning of this paper.

The final blow to the traditional framework for productivity measurement was administered by the Panel to Review Productivity Statistics of the National Research Council, chaired by Albert Rees. The Rees Report of 1979, *Measurement and Interpretation of Productivity*, became the cornerstone of a new measurement framework for the official productivity statistics. This was implemented by the Bureau of Labor Statistics (BLS), the U.S. government agency responsible for these statistics.

Under the leadership of Jerome Mark and Edwin Dean the BLS Office of Productivity and Technology undertook the construction of a production account for the U.S. economy with measures of capital and labor inputs and total factor productivity, renamed *multifactor productivity*. A detailed history of the BLS productivity measurement program is presented by Dean and Michael Harper (2001). The BLS (1983) framework was based on GNP rather than NNP and included a constant quality index of capital input, displacing two of the key conventions of the traditional framework of Kuznets and Solow.

[1] See Jorgenson and Griliches (1967), Table IX, p. 272. We also attributed thirteen percent of growth to the relative utilization of capital, measured by energy consumption as a proportion of capacity; however, this is inappropriate at the aggregate level, as Denison (1974), p. 56, pointed out. For additional details, see Jorgenson, Gollop, and Fraumeni (1987), especially pp. 179–181.

However, BLS retained hours worked as a measure of labor input until July 11, 1994, when it released a new multifactor productivity measure including a constant quality index of labor input as well. Meanwhile, BEA (1986) had incorporated a constant quality price index for computers into the national accounts – over the strenuous objections of Edward F. Denison (1989). This index was incorporated into the BLS measure of output, completing the displacement of the traditional framework of economic measurement by the conventions employed in my paper with Griliches.

Jorgenson and Steven Landefeld (2006) have developed a new architecture for the U.S. national income and product accounts (NIPAs) that includes prices and quantities of capital services for all productive assets in the U.S. economy. The incorporation of the price and quantity of capital services into the United Nations' *System of National Accounts 2008* (2009) was approved by the United Nations Statistical Commission at its February-March 2007 meeting. Schreyer, then head of national accounts at the OECD, prepared an OECD Manual, *Measuring Capital*, published in 2009. This provides detailed recommendations on methods for the construction of prices and quantities of capital services.

In Chapter 20 of *SNA 2008* (page 415), estimates of capital services are described as follows: "By associating these estimates with the standard breakdown of value added, the contribution of labor and capital to production can be portrayed in a form ready for use in the analysis of productivity in a way entirely consistent with the accounts of the System." The measures of capital and labor inputs in the prototype system of U.S. national accounts presented by Jorgenson and Landefeld (2006) and updated by Jorgenson (2009b) are consistent with the OECD productivity manual, *SNA 2008*, and the OECD Manual, *Measuring Capital*. The volume measure of input is a quantity index of capital and labor services, while the volume measure of output is a quantity index of investment and consumption goods. Productivity is the ratio of output to input.

The new architecture for the U.S. national accounts was endorsed by the Advisory Committee on Measuring Innovation in the 21st Century Economy to the U.S. Secretary of Commerce (page 8), Carlos Guttierez:

> The proposed new 'architecture' for the NIPAs would consist of a set of income statements, balance

> sheets, flow of funds statements, and productivity estimates for the entire economy and by sector that are more accurate and internally consistent. The new architecture will make the NIPAs much more relevant to today's technology-driven and globalizing economy and will facilitate the publication of much more detailed and reliable estimates of innovation's contribution to productivity growth.

The Advisory Committee was established on December 6, 2007, with ten members from the business community, including Carl Schramm, President and CEO of the Kauffman Foundation and chair of the Committee. The Committee also had five academic members, including myself. The Advisory Committee met on February 22 and September 12, 2007, to discuss its recommendations. The final report was released on January 18, 2008.

In response to the Advisory Committee's recommendations, BEA and BLS have produced an initial set of multifactor productivity estimates integrated with the NIPAs. The results are reported by Michael Harper, Brent Moulton, Steven Rosenthal, and David Wasshausen (2009) and will be updated annually. This is a critical step in implementing the new architecture. Estimates of productivity are essential for projecting the potential growth of the U.S. economy, as demonstrated by Jorgenson, Ho, and Stiroh (2008). The omission of productivity statistics from the NIPAs and the 1993 SNA has been a serious barrier to assessing potential growth.

Measuring Productivity at the Industry Level

The new framework for productivity measurement has posed an important challenge. This is to develop a system of production accounts for individual sectors of the U.S. economy, such as agriculture and computers. A measure of output per unit of input for agriculture was introduced by Glen Barton and Martin Cooper (1948), drawing on earlier research at the Bureau of Agricultural Economics in the U.S. Department of Agriculture (USDA).

Barton and Cooper (1948) demonstrated that most of the growth of agricultural output was due to an increase in productivity, rather than the growth of capital and labor inputs. Although contrary to the views of Schultz (1956), Barton and Cooper's conclusion has been repeatedly corroborated by subsequent research on agricultural productivity.[2] This research led to the publication of the first official statistics on total factor productivity in agriculture by the USDA in 1960. The official statistics for agricultural productivity were described in detail by Ralph Loomis and Barton (1961).

A complete system of production accounts for industrial sectors of the U.S. economy was constructed by Gollop and Jorgenson (1980) and Jorgenson, Gollop, and Fraumeni (1987). The system incorporates a consistent time series of input-output tables and provides the basis for the industry-level production accounts presented by Schreyer's OECD *Productivity Manual* (2001). Details on the construction of the time series of input-output tables are presented by Jorgenson, Ho, and Stiroh (2005, Chapter 4, pp. 87–146).

The USDA methodology for productivity measurement has been subjected to detailed criticism, initiated by the highly influential critique of Griliches (1960). A joint USDA/AAEA committee, chaired by Bruce Gardner, published a set of recommendations for revision of the official estimates in 1980. In 1985 this led to a response by Eldon Ball of the Economic Research Service, who largely adopted the methodology of Gollop and Jorgenson, but employed much more detailed data on agricultural output, as well as inputs of capital, labor, and intermediate inputs.

Ball's research became the basis for a new version of USDA's official statistics on agricultural productivity in 1991. The Gardner committee also presented a history of research on the growth of agricultural productivity. This was updated by Trueblood and Ruttan (1995), who compared thirteen alternative estimates of agricultural productivity growth. These included Jorgenson and Gollop (1992), who presented an updated version of their estimates of productivity growth for farm and nonfarm sectors of the U.S. economy.

Robert Evenson and Wallace Huffman (2006) have undertaken a two-decade program of research to improve statistics on agricultural productivity and its determinants. This includes measures of agricultural productivity at the level of individual states. Again led by Eldon Ball, the Economic Research

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[2] See, for example, Michael Trueblood and Vernon Ruttan (1995), Ball, Jean-Christophe Bureau, Nehring, and Agapi Sonwaru (1997), and the Economic Research Service agricultural productivity website: http://www.ers.usda.gov/Data/agproductivity/

Service of USDA developed official measures of agricultural productivity at the state level, described by Ball, Gollop, Allison Kelly-Hawk, and Gregory Swinand (1999) and Ball, Jean-Pierre Butault, and Nehring (2002). The latest version is used in Huffman's (2009) study of the impact of public agricultural research on productivity growth. Estimates of agricultural productivity by state are also presented by Albert Acquaye, Julian Alston, and Philip Pardey (2002).

The approach to growth accounting presented in my 1987 book with Gollop and Fraumeni, the USDA's official statistics on agricultural productivity, and the official statistics on aggregate productivity published by the BLS in 1994 have been recognized as the international standard. This standard is discussed in Schreyer's (2001) OECD Manual, *Measuring Productivity*. The expert advisory group for this Manual was chaired by Dean, former Associate Commissioner for Productivity at the BLS and leader of the successful effort to implement the Rees Report (1979).

Reflecting the international consensus on productivity measurement, the Advisory Committee on Measuring Innovation in the 21st Century Economy to the U.S. Secretary of Commerce (2008, page 7) recommended that the Bureau of Economic Analysis (BEA) should:

> Develop annual, industry-level measures of total factor productivity by restructuring the NIPAs to create a more complete and consistent set of accounts integrated with data from other statistical agencies to allow for the consistent estimation of the contribution of innovation to economic growth.

The principles for constructing industry-level production accounts are discussed by Fraumeni, Harper, Susan Powers, and Robert Yuskavage (2006). Disaggregating the production account by industrial sector requires the fully integrated system of input-output accounts and accounts for gross product originating by industry, described by Ann Lawson, Brian Moyer, Sumiye Okubo and Mark Planting (2006), and Moyer, Marshall Reinsdorf, and Yuskavage (2006). This has been combined with the measures of capital, labor, and intermediate inputs by industry presented by Jorgenson, Ho, Jon Samuels, and Stiroh (2007), to generate the prototype system of production accounts by sector given below.

Jorgenson, Ho, and Stiroh (2005), the EU KLEMS project described by O'Mahony and Timmer (2009), and the studies presented in Jorgenson (2009a), *The Economics of Productivity,* have made possible the international comparisons of patterns of structural change presented by Jorgenson and Timmer (2009). Ball, Jean-Pierre Butault, Carlos San Juan Mesonada, and Ricardo Mora (2007) have provided international comparisons of agricultural productivity between the U.S. and the EU, using the same methodology. Efforts are underway to extend the EU KLEMS framework to important developing and transition economies, including Argentina, Brazil, Chile, China, India, Indonesia, Mexico, Russia, Turkey, and Taiwan.

Economic Impact of Information Technology

Research on the impact of investment in IT equipment and software on economic growth is summarized by Jorgenson (2009a) in *The Economics of Productivity*. Jorgenson, Ho, Samuels, and Stiroh (2007) have traced the American growth resurgence after 1995 to sources within individual industries. Output and productivity for the IT-producing industries have been separately identified. The remaining industries are divided between the IT-using industries, those that are particularly intensive in the utilization of information technology equipment and software, and the Non-IT industries. The IT-using industries are defined as those with 15 percent or more of capital input in the form of IT equipment and software. More details are provided by Jorgenson and Charles W. Wessner (2007).

The most distinctive features of IT assets are the rapid declines in prices of these assets, as well as relatively high rates of depreciation. The price of an asset is transformed into the price of the corresponding capital input by an annualization factor known as the *cost of capital*. The cost of capital includes the nominal rate of return, the rate of depreciation, and the rate of capital loss due to declining prices. The distinctive characteristics of IT prices – high rates of price decline and rates of depreciation – imply that cost of capital for the price of IT capital input is very large relative to the cost of capital for the price of Non-IT capital input.

The prices of capital inputs are essential for assessing the contribution of investment in IT equipment and software to economic growth. This contribution is the relative share of IT equipment and software in the value of output, multiplied by the rate of growth of IT capital inputs. A substantial part of the growing contribution of capital input in the U.S. can be traced to the change in composition of investment associated with the growing importance of IT equipment and software.

The contributions of college-educated and non-college-educated workers to U.S. economic growth is given by the relative shares of these workers in the value of output, multiplied by the growth rates of their hours worked. Personnel with a college degree or higher level of education correspond closely with "knowledge workers" who deal with information. Of course, not every knowledge worker is college-educated and not every college graduate is a knowledge worker.

Productivity growth is the key economic indicator of *innovation*. Economic growth can take place without innovation through *replication* of established technologies. Investment increases the availability of these technologies, while the labor force expands as population grows. With only replication and without innovation, output will increase in proportion to capital and labor inputs, as suggested by Schultz (1956, 1962). By contrast the successful introduction of new products and new or altered processes, organization structures, systems, and business models generates growth of output that exceeds the growth of capital and labor inputs. This results in growth in multifactor productivity or output per unit of input.

Innovation is often described as the predominant source of economic growth. This finding is called "Solow's surprise" by William Easterly (2001) and is listed as one of the "stylized facts" about economic growth by Robert King and Sergio Rebelo (1999). However, Table 1 shows that the growth of productivity was far less important than the contributions of capital and labor inputs. For the period 1960–2007, productivity accounts for less than twelve percent of U.S. economic growth, slightly less than the fifteen percent of growth for 1945–1965 estimated by Jorgenson and Griliches (1967). The contribution of capital input accounts for 60 percent of growth during the period 1960–2007, while labor input accounts for 28 percent.

The great bulk of U.S. economic growth is due to replication of established technologies rather than innovation. This is despite the fact that growth in industries like agriculture and computers is due mainly to innovation. Innovation is obviously far more challenging and subject to much greater risk. The diffusion of successful innovation requires mammoth financial commitments. These fund the investments that replace outdated products and processes and establish new organization structures, systems, and business models. Although innovation accounts for a relatively minor portion of economic growth, this portion is vital for maintaining gains in the U.S. standard of living in the long run.

Turning to the sources of the U.S. growth acceleration after 1995, Table 1 shows that IT capital input was by far the most significant. Growth increased by 1.10 percent in 1995–2000, while the contribution of IT capital input increased by 0.61 percent. Many industries substituted IT equipment and software for Non-IT investment, leading to a decline in the contribution of Non-IT investment to growth. The increased contribution of labor input in 1995–2000 was almost evenly divided between college and non-college workers. The pace of innovation clearly accelerated during the IT investment boom and the contribution of productivity to the acceleration of U.S. economic growth was slightly above the contribution of IT investment.

Jorgenson, Ho, and Stiroh (2008) have shown that the rapid pace of U.S. economic growth after 1995 was not sustainable. After the dot-com crash in 2000 the overall growth rate dropped to well below the long-term average of 1960–1995. The contribution of investment also declined below the 1960–1995 average, but the shift from Non-IT to IT capital input continued. The contribution of labor input dropped precipitously, accounting for most of the decline in economic growth during the "jobless" recovery that followed. The contribution to growth by college-educated workers continued at a reduced rate, but that of non-college workers was negative.

The most remarkable feature of the recovery after 2000 was the continued growth in productivity, indicating a renewed surge of innovation. Table 2 shows that the IT-producing industries comprise 1.8 percent of the GDP, the IT-using industries 41.4 percent, and Non-IT industries 56.5 percent. Table 3 decomposes productivity growth into the contributions of the IT-producing industries, IT-using industries, and Non-IT industries.

During 1960–1995 the IT-producing industries accounted for 57 percent of innovation, far out of proportion to their proportion of the GDP. In the IT investment boom of 1995–2000

Table 1. Growth in Aggregate Value Added and the Sources of Growth Aggregate Production Possibility Frontier

	1960–2007	1960–1995	1995–2000	2000–2007	1995–2000 less 1960–1995	2000–2007 less 1960–1995
			Contributions			
Value-Added	3.45	3.42	4.52	2.78	1.10	−0.64
IT-Producing Industries	0.31	0.24	0.81	0.28	0.57	0.03
IT-Using Industries	1.61	1.60	2.24	1.19	0.64	−0.42
Non-IT Industries	1.53	1.59	1.45	1.30	−0.14	−0.29
Capital Input	2.07	2.11	2.32	1.67	0.21	−0.44
IT Capital	0.49	0.41	1.02	0.49	0.61	0.08
Non-IT Capital	1.58	1.70	1.30	1.18	−0.40	−0.52
Labor Input	0.97	1.04	1.30	0.40	0.26	−0.64
College Labor	0.58	0.59	0.75	0.43	0.15	−0.16
Non-college Labor	0.37	0.43	0.55	−0.04	0.12	−0.47
Aggregate TFP	0.41	0.28	0.90	0.72	0.62	0.44
			Quality and Stock Contributions			
Contribution of Capital Quality	0.58	0.56	0.89	0.46	0.33	−0.10
Contribution of Capital Stock	1.48	1.55	1.43	1.21	−0.12	−0.34
Contribution of Labor Quality	0.23	0.24	0.20	0.22	−0.03	−0.01
Contribution of Labor Hours	0.74	0.80	1.09	0.17	0.29	−0.63

Notes: All figures are average annual percentages. The contribution of an output or input is the growth rate multiplied by the average value share. The IT-producing, IT-using, and non-IT industries are defined in Table 2.10. IT capital includes computer hardware, computer software, and telecommunications equipment.

Table 2. Growth and Shares of Aggregate Variables Aggregate Production Possibility Frontier

	1960–2006	1960–1995	1995–2000	2000–2007	1995–2000 less 1960–1995
			Growth Rates		
Value-Added	3.45	3.42	4.52	2.78	1.10
IT-Producing Industries	15.92	15.44	27.35	10.19	11.91
IT-Using Industries	3.92	4.01	5.08	2.68	1.08
Non-IT Industries	2.70	2.73	2.75	2.48	0.02
Capital Input	4.73	4.86	5.23	3.72	0.37
IT Capital	17.86	19.01	21.15	9.73	2.13
Non-IT Capital	3.86	4.12	3.30	2.96	−0.82
Labor Input	1.73	1.84	2.34	0.74	0.49
College Labor	3.62	4.08	3.19	1.67	−0.89
Non-college Labor	0.95	1.05	1.71	−0.10	0.65
			Shares		
Value-Added	100.0	100.0	100.0	100.0	0.0
IT-Producing Industries	1.8	1.5	3.0	2.8	1.5
IT-Using Industries	41.4	40.4	44.2	44.4	3.8
Non-IT Industries	56.5	57.8	52.7	52.6	−5.1
Capital Input	43.7	43.3	44.4	44.9	1.1
IT Capital	2.9	2.2	4.8	5.1	2.6
Non-IT Capital	40.7	41.1	39.6	39.8	−1.5
Labor Input	56.3	56.7	55.6	55.1	−1.1
College Labor	17.7	15.2	23.4	25.7	8.2
Non-college Labor	38.7	41.4	32.2	29.4	−9.3

Notes: Growth rates are average annual percentage. Shares are the mean two-period average for each period in percentages.

Table 3. Aggregate Reallocation Effects

	1960–2007	1960–1995	1995–2000	2000–2007	1995–2000 less 1960–1995	1995–2007 less 1960–1995
Aggregate Production Possibility Frontier vs. Aggregate Production Function						
Aggregate Production Function Value-Added	3.11	2.91	3.83	3.63	0.92	0.72
Aggregate Production Possibility Frontier Value-Added	3.45	3.42	4.52	2.78	1.10	−0.64
Reallocation of Value-Added	−0.34	−0.51	−0.69	0.85	−0.18	1.36
Aggregate Production Possibility Frontier vs. Direct Aggregation Across Industries						
Aggregate TFP	# REF!	# REF!	# REF!	# REF!	# REF!	# REF!
Domar-Weighted Productivity	0.33	0.22	0.67	0.67	0.45	0.46
IT-Producing Industries	0.22	0.16	0.53	0.29	0.37	0.13
IT-Using Industries	0.20	0.16	0.16	0.44	0.00	0.28
Non-IT Industries	−0.09	−0.11	−0.03	−0.06	0.08	0.05
Reallocation of Capital Input	0.10	0.08	0.21	0.09	0.13	0.01
Reallocation of Labor Input	−0.02	−0.02	0.03	−0.05	0.05	−0.03

Notes: All figures are average annual percentage. The contribution of an output or input is the growth rate multiplied by the average value share.

these industries accounted for 60 percent of the substantially increased contribution of innovation. After the dot-com crash this contribution to innovation receded toward the long term average of 1960–1995. How, then, did innovation accelerate after 2000?

Table 3 shows that rates of innovation in the Non-IT industries were negative throughout the period 1960–2007. Negative rates of growth are associated the exhaustion of resources in the mining industries and increased regulation in industries like petroleum refining. The emergence of rapid innovation in the IT-using industries, making up two-fifths of the U.S. economy, was the main source of sustained productivity growth in 2000–2007. Innovation in these industries had been unchanged from 1960–1995 to 1995–2000 as the IT-using industries were nearly swamped by increased investments in IT equipment and software.

The locus of U.S. innovation is revealed by the contribution of productivity growth in the industries listed in Tables 4 and 5a to U.S. economic growth during 1960–2007. The leaders in innovation among IT-using sectors, wholesale and retail trade, head the list. The leading firms like Walmart and Cisco have integrated supply chains around the world. These supply chains link electronic cash registers at retail outlets and business-to-business ordering systems with order dispatch and transportation scheduling at remote factories.

Next on the list of the leaders in innovation are two IT-producing sectors, semiconductors and computers. These sectors have sustained very rapid growth, powered by innovation, throughout the period. Leading firms such as Intel and IBM have generated truly staggering rates of growth through incessant product and process innovation. The rapid pace of development of IT equipment has continued through successive generations of technology, beginning with mainframe computers and continuing with minicomputers and then personal computers, followed by the recent development of "cloud computing", accessed through the Internet.

Agriculture occupies an important position among the industries dominated by innovation, contrary to the views of Schultz (1956), who attributed the growth of agricultural output to replication rather than innovation. Broadcasting and telecommunications services, the industry providing the hardware and software support for the vast expansion of the Internet, is next on the list of contributors to productivity growth. Voice, data, and video communications moved onto the Internet as broadband services become available to households along with mobile and landline communications services. The list of rapidly innovating industries is completed by software publishing, a very significant IT-producing sector.

Innovation and the World Economy

The long reach of globalization is evident in the surge in IT investment in the world economy

Table 4. Industry Contribution to Aggregate Value-Added and TFP Growth, 1960–2007

	Value-Added			Productivity		
	V-A Weight	V-A Growth	Contribution to Aggregate V-A	Domar Weight	TFP Growth	Contribution to Aggregate TFP
Farms	0.018	2.59	0.036	0.042	1.40	0.050
Forestry fishing and related activities	0.003	2.00	0.006	0.006	−0.77	−0.005
Oil and gas extraction	0.009	−1.66	−0.019	0.017	−2.25	−0.049
Mining except oil and gas	0.005	1.92	0.008	0.009	0.39	0.001
Support activities for mining	0.002	1.66	0.005	0.004	−0.44	−0.003
Utilities	0.020	1.52	0.030	0.037	−0.52	−0.026
Construction	0.043	0.88	0.034	0.093	−0.79	0.070
Wood products	0.004	1.42	0.006	0.011	0.10	0.000
Nonmetallic mineral products	0.006	1.45	0.009	0.013	0.16	0.001
Primary metals	0.011	−1.22	−0.006	0.033	−0.23	−0.010
Fabricated metal products	0.015	1.77	0.028	0.034	0.31	0.009
Machinery	0.016	2.99	0.058	0.037	0.33	0.012
Electrical equipment appliances and components	0.007	2.02	0.018	0.017	0.23	0.001
Motor vehicle bodies and trailers and parts	0.014	2.14	0.038	0.051	0.36	0.015
Other transportation equipment	0.010	1.21	0.015	0.024	0.18	0.004
Furniture and related products	0.004	2.24	0.009	0.008	0.46	0.004
Miscellaneous manufacturing	0.005	3.60	0.020	0.013	0.96	0.012
Food and beverage and tobacco products	0.017	1.30	0.027	0.078	0.04	0.006
Textile mills and textile product mills	0.005	2.68	0.017	0.016	1.18	0.018
Appared and leather and allied products	0.007	−0.35	0.006	0.018	0.31	0.001
Paper products	0.007	1.28	0.013	0.020	0.05	0.001
Printing and related support activities	0.006	1.85	0.011	0.011	0.06	0.000
Petroleum and coal products	0.004	3.65	0.008	0.029	0.18	0.004
Chemical products	0.017	2.83	0.052	0.051	0.06	0.002
Plastics and rubber products	0.007	3.81	0.026	0.017	0.47	0.008
Wholesale Trade	0.048	6.39	0.308	0.076	1.94	0.150
Retail Trade	0.060	3.86	0.227	0.083	1.38	0.114
Air transportation	0.004	8.34	0.035	0.010	1.60	0.016
Rail transportation	0.007	0.57	0.003	0.010	1.59	0.016
Water transportation	0.001	5.05	0.005	0.004	0.68	0.002
Truck transportation	0.009	3.87	0.036	0.020	0.76	0.014
Transit and ground passenger transportation	0.002	0.60	0.001	0.004	−1.01	−0.005
Pipeline transportation	0.001	3.94	0.005	0.004	0.52	0.002
Other transportation and support activities	0.006	3.82	0.023	0.009	1.07	0.009
Warehousing and storage	0.002	4.95	0.010	0.003	1.69	0.005
Motion picture and sound recording industries	0.003	3.23	0.007	0.006	0.14	0.000
Broadcasting and telecommunications	0.021	6.52	0.134	0.038	1.15	0.043
Information and data processing services	0.002	6.61	0.018	0.004	0.00	0.006
Federal Reserve banks credit intermediation	0.025	3.82	0.091	0.036	−1.57	−0.055

Continued.

Table 4. Continued

	Value-Added			Productivity		
	V-A Weight	V-A Growth	Contribution to Aggregate V-A	Domar Weight	TFP Growth	Contribution to Aggregate TFP
Securities commodity contracts and investr	0.007	9.17	0.094	0.012	2.04	0.056
Insurance carriers and related activities	0.017	3.22	0.054	0.037	−0.34	−0.012
Funds trusts and other financial vehicles	0.001	−4.65	−0.005	0.006	−1.92	−0.012
Rental and leasing services and lessors of in	0.008	4.84	0.035	0.013	−2.09	−0.034
Legal services	0.010	2.46	0.021	0.015	−1.61	−0.022
Computer systems design and related servi	0.005	7.45	0.039	0.006	−1.60	−0.004
Miscellaneous professional scientific and te	0.027	5.12	0.137	0.043	0.12	0.009
Management of companies and enterprises	0.016	2.77	0.041	0.025	−0.35	−0.010
Administrative and support service	0.015	5.21	0.075	0.024	−0.08	0.001
Waste management and remediation service	0.002	3.73	0.007	0.005	0.44	0.002
Educational services	0.007	2.77	0.017	0.012	−0.56	−0.007
Ambulatory health care services	0.024	3.33	0.078	0.032	−1.02	−0.028
Hospitals Nursing and residential care facilitate	0.018	2.78	0.036	0.036	−0.88	−0.037
Social assistance	0.003	5.33	0.017	0.006	0.39	0.003
Performing arts spectator sports museums a	0.003	3.51	0.010	0.005	0.23	0.001
Amusements gambling and recreation industries	0.004	4.06	0.014	0.005	0.08	0.000
Accommodation	0.007	4.08	0.027	0.010	0.82	0.008
Food services and drinking places	0.014	2.21	0.031	0.032	0.05	0.002
Other services except government	0.023	1.55	0.037	0.042	−0.40	−0.020
Federal General government	0.036	0.60	0.024	0.063	0.16	0.012
Federal Government enterprises	0.007	1.02	0.007	0.009	−0.24	−0.003
S&L General Government	0.066	2.53	0.157	0.096	−0.17	−0.020
S&L Government enterprises	0.007	1.90	0.013	0.015	−0.83	−0.012
Computer and peripheral equipment manufacturing	0.003	35.35	0.093	0.008	10.77	0.086
Communications equipment manufacturing	0.002	4.12	0.010	0.007	0.74	0.004
Semiconductor and other electronic components	0.004	22.14	0.103	0.010	8.86	0.099
Other electronic products	0.005	3.80	0.021	0.014	0.82	0.010
Newspaper, periodical, book publishers	0.006	0.04	0.002	0.013	−1.73	−0.022
Software publishing	0.002	21.35	0.045	0.004	9.01	0.032
Real estate	0.050	3.34	0.166	0.066	−0.82	−0.051
Household	0.149	4.56	0.683	0.149	0.00	0.000
Sum	1.000		3.446	1.814		0.332

Notes: All figures are annual average. Value-added weights are industry value-added as a share of aggregate value-added. Domar weights are industry output as a share of aggregate value-added. A contribution is a share-weighted growth rate.

Table 5a. Industry Contributions to Aggregate Capital and Labor Input Growth, 1960–2007

	Capital			Labor		
	Total	IT	Non-IT	Total	College	Non-College
Farms	0.009	0.000	0.008	−0.023	0.002	−0.025
Forestry fishing and related activities	0.006	0.001	0.005	0.005	0.001	0.004
Oil and gas extraction	0.028	0.002	0.025	0.003	0.003	0.001
Mining except oil and gas	0.009	0.001	0.008	−0.002	0.000	−0.002
Support activities for mining	0.006	0.001	0.005	0.003	0.001	0.001
Utilities	0.054	0.007	0.046	0.003	0.003	0.000
Construction	0.017	0.006	0.010	0.088	0.019	0.069
Wood products	0.004	0.001	0.004	0.002	0.001	0.001
Nonmetallic mineral products	0.009	0.003	0.005	−0.001	0.001	−0.001
Primary metals	0.011	0.004	0.007	−0.007	0.001	−0.009
Fabricated metal products	0.014	0.006	0.008	0.005	0.002	0.003
Machinery	0.044	0.017	0.027	0.003	0.003	0.003
Electrical equipment appliances and components	0.015	0.003	0.013	0.002	0.002	0.000
Motor vehicles bodies and trailers and parts	0.013	0.006	0.008	0.009	0.006	0.003
Other transportation equipment	0.008	0.004	0.005	0.002	0.006	−0.004
Furniture and related products	0.003	0.001	0.002	0.002	0.001	0.001
Miscellaneous manufacturing	0.005	0.002	0.003	0.004	0.003	0.000
Food and beverage and tobacco products	0.023	0.005	0.017	−0.002	0.005	−0.007
Textile mills and textile product mills	0.003	0.001	0.002	−0.003	0.001	−0.004
Apparel and leather and allied products	0.013	0.001	0.011	−0.007	0.001	−0.008
Paper products	0.010	0.002	0.008	0.002	0.002	0.000
Printing and related support activities	0.007	0.002	0.005	0.004	0.003	0.002
Petroleum and coal products	0.006	0.003	0.003	−0.002	0.000	−0.003
Chemical products	0.044	0.012	0.032	0.007	0.008	−0.001
Plastics and rubber products	0.010	0.001	0.009	0.009	0.002	0.006
Wholesale Trade	0.098	0.029	0.068	0.060	0.033	0.027
Retail Trade	0.061	0.018	0.043	0.052	0.027	0.026
Air transportation	0.010	0.007	0.003	0.009	0.005	0.004
Rail transportation	0.002	0.001	0.001	−0.015	0.000	−0.015
Water transportation	0.003	0.001	0.002	0.000	0.000	0.000
Truck transportation	0.008	0.001	0.007	0.014	0.002	0.012
Transit and ground passenger transportation	0.004	0.003	0.002	0.001	0.001	0.000
Pipeline transportation	0.003	0.002	0.002	0.000	0.000	0.000
Other transportation and support activities	0.004	0.002	0.003	0.010	0.004	0.006
Warehousing and storage	0.001	0.001	0.001	0.004	0.001	0.003
Motion picture and sound recording industries	0.004	0.001	0.003	0.003	0.003	0.000
Broadcasting and telecommunications	0.070	0.046	0.024	0.021	0.012	0.010
Information and data processing services	0.006	0.005	0.001	0.006	0.004	0.002
Federal Reserve banks credit intermediation	0.116	0.051	0.065	0.030	0.020	0.011
Securities commodity contracts and invest	0.012	0.011	0.001	0.026	0.022	0.004

Continued.

Table 5a. Continued

	Capital			Labor		
	Total	IT	Non-IT	Total	College	Non-College
Insurance carriers and related activities	0.045	0.022	0.023	0.021	0.017	0.004
Funds trusts and other financial vehicles	0.005	0.003	0.002	0.002	0.002	0.000
Rental and leasing services and lessors of in	0.063	0.032	0.030	0.006	0.003	0.004
Legal services	0.024	0.011	0.014	0.019	0.015	0.004
Computer systems design and related servic	0.010	0.009	0.001	0.033	0.024	0.010
Miscellaneous professional scientific and te	0.056	0.038	0.019	0.072	0.052	0.020
Management of companies and enterprises	0.019	0.014	0.004	0.033	0.027	0.006
Administrative and support services	0.018	0.010	0.008	0.056	0.018	0.038
Waste management and remediation service	0.003	0.001	0.002	0.003	0.001	0.002
Educational services	0.005	0.003	0.002	0.020	0.015	0.004
Ambulatory health care services	0.035	0.007	0.028	0.071	0.045	0.026
Hospitals Nursing and residential care facilitate	0.019	0.006	0.013	0.054	0.026	0.028
Social assistance	0.002	0.000	0.001	0.012	0.005	0.008
Performing arts spectator sports museums a	0.001	0.001	0.001	0.008	0.005	0.002
Amusements gambling and recreation industries	0.006	0.001	0.005	0.008	0.003	0.005
Accommodation	0.010	0.001	0.009	0.009	0.004	0.005
Food services and drinking places	0.007	0.002	0.006	0.023	0.007	0.015
Other services except government	0.042	0.005	0.037	0.014	0.008	0.007
Federal General government	0.014	0.006	0.009	−0.003	0.008	−0.011
Federal Government enterprises	0.009	0.002	0.007	0.001	0.001	0.000
S&L General Government	0.063	0.013	0.050	0.114	0.084	0.030
S&L Government enterprises	0.014	0.002	0.012	0.011	0.002	0.009
Computer and peripheral equipment manufacturing	0.004	0.002	0.002	0.003	0.003	0.001
Communications equipment manufacturing	0.004	0.002	0.002	0.002	0.002	0.000
Semiconductor and other electronic components	0.005	0.003	0.002	−0.001	0.002	−0.003
Other electronic products	0.006	0.004	0.003	0.004	0.005	−0.001
Newspaper; periodical; book publishers	0.015	0.009	0.006	0.009	0.007	0.003
Software publishing	0.008	0.006	0.002	0.006	0.005	0.001
Real estate	0.201	0.003	0.198	0.016	0.009	0.006
Household	0.683	0.057	0.626	0.000	0.000	0.000
Sum	2.164	0.543	1.622	0.949	0.611	0.339

Notes: All figures are annual averages. Value-added weights are industry value-added as a share of aggregate value-added. Domar weights are industry output as a share of aggregate value-added. A contribution is a share-weighted growth rate.

Table 5b. Industry Contributions to Aggregate Capital and Labor Input Growth, 1960–2006

	Capital			Labor		
	Total	IT	Non-IT	Total	College	Non-College
Farms	0.011	0.001	0.010	−0.010	0.001	−0.011
Forestry fishing and related activities	0.007	0.000	0.007	0.004	0.001	0.003
Oil and gas extraction	0.026	0.002	0.024	0.001	0.002	0.000
Mining except oil and gas	0.005	0.001	0.005	−0.002	0.001	−0.002
Support activities for mining	0.004	0.001	0.003	0.003	0.001	0.001
Utilities	0.042	0.006	0.036	0.002	0.003	−0.001
Construction	0.019	0.007	0.013	0.100	0.020	0.080
Wood products	0.004	0.001	0.003	0.002	0.001	0.000
Nonmetallic mineral products	0.006	0.002	0.004	−0.001	0.001	−0.002
Primary metals	0.008	0.002	0.006	−0.009	0.001	−0.010
Fabricated metal products	0.013	0.003	0.010	0.004	0.002	0.002
Machinery	0.026	0.008	0.018	0.003	0.004	−0.001
Computer and electronic products	0.021	0.009	0.012	0.011	0.014	−0.003
Electrical equipment appliances and components	0.011	0.002	0.009	0.002	0.003	0.000
Motor vehicles bodies and trailers and parts	0.012	0.004	0.008	0.009	0.006	0.003
Other transportation equipment	0.007	0.003	0.004	0.001	0.005	−0.005
Furniture and related products	0.003	0.000	0.002	0.002	0.001	0.001
Miscellaneous manufacturing	0.004	0.001	0.003	0.003	0.003	0.000
Food and beverage and tobacco products	0.016	0.003	0.012	−0.003	0.005	−0.008
Textile mills and textile product mills	0.002	0.000	0.002	−0.004	0.001	−0.005
Apparel and leather and allied products	0.007	0.000	0.006	−0.009	0.001	−0.010
Paper products	0.008	0.001	0.007	0.002	0.002	0.000
Printing and related support activities	0.006	0.001	0.005	0.004	0.003	0.002
Petroleum and coal products	0.005	0.002	0.003	−0.003	0.000	−0.003
Chemical products	0.036	0.007	0.028	0.007	0.008	−0.002
Plastics and rubber products	0.009	0.001	0.009	0.009	0.003	0.007
Wholesale Trade	0.112	0.029	0.083	0.063	0.033	0.030
Retail Trade	0.062	0.013	0.049	0.056	0.029	0.027
Air transportation	0.011	0.006	0.005	0.009	0.005	0.004
Rail transportation	−0.002	0.001	−0.002	−0.016	0.000	−0.016
Water transportation	0.002	0.001	0.001	0.000	0.001	0.000
Truck transportation	0.010	0.001	0.009	0.014	0.002	0.012
Transit and ground passenger transportation	0.001	0.001	0.000	0.000	0.001	0.000
Pipeline transportation	0.002	0.001	0.001	0.000	0.000	0.000
Other transportation and support activities	0.003	0.001	0.002	0.010	0.004	0.006
Warehousing and storage	0.001	0.000	0.001	0.004	0.001	0.003
Publishing industries (includes software)	0.009	0.005	0.004	0.016	0.014	0.002

Continued.

Table 5b. Continued

	Capital			Labor		
	Total	IT	Non-IT	Total	College	Non-College
Motion picture and sound recording industries	0.004	0.001	0.003	0.002	0.002	0.000
Broadcasting and telecommunications	0.069	0.044	0.025	0.018	0.011	0.007
Information and data processing services	0.007	0.005	0.002	0.007	0.005	0.002
Federal Reserve banks credit intermediatior	0.116	0.049	0.067	0.034	0.023	0.012
Securities commodity contracts and invest	0.013	0.011	0.002	0.027	0.023	0.004
Insurance carriers and related activities	0.044	0.018	0.026	0.023	0.019	0.005
Funds trusts and other financial vehicles	0.004	0.002	0.003	0.002	0.002	0.000
Real estate	0.391	0.005	0.374	0.012	0.007	0.005
Rental and leasing services and lessors of i	0.065	0.031	0.035	0.006	0.002	0.003
Legal services	0.024	0.007	0.017	0.019	0.015	0.004
Computer systems design and related servi	0.018	0.014	0.004	0.025	0.019	0.007
Miscellaneous professional scientific and te	0.077	0.046	0.031	0.069	0.047	0.023
Management of companies and enterprises	0.014	0.010	0.004	0.031	0.026	0.004
Administrative and support services	0.026	0.012	0.014	0.059	0.017	0.041
Waste management and remediation servic	0.002	0.001	0.002	0.003	0.001	0.002
Educational services	0.005	0.002	0.003	0.021	0.017	0.005
Ambulatory health care services	0.049	0.006	0.043	0.072	0.040	0.032
Hospitals Nursing and residential care facilitate	0.023	0.005	0.018	0.055	0.026	0.029
Social assistance	0.002	0.001	0.002	0.013	0.006	0.007
Performing arts spectator sports museums a	0.002	0.001	0.001	0.006	0.005	0.002
Amusements gambling and recreation indu	0.005	0.001	0.004	0.009	0.003	0.006
Accommodation	0.006	0.001	0.005	0.011	0.004	0.007
Food services and drinking places	0.006	0.001	0.005	0.028	0.008	0.020
Other services except government	0.025	0.003	0.021	0.028	0.012	0.016
Federal General government	0.014	0.007	0.007	0.015	0.018	−0.003
Federal Government enterprises	0.004	0.001	0.003	0.003	0.002	0.001
S&L General Government	0.028	0.008	0.020	0.192	0.136	0.056
S&L Government enterprises	0.007	0.002	0.005	0.016	0.002	0.014
Sum	1.577	0.422	1.143	1.091	0.677	0.414

Notes: All figures are annual average. Value-added weights are industry value-added as a share of aggregate value-added. Domar weights are industry output as a share of aggregate value-added. A contribution is a share-weighted growth rate.

Table 6. The world economy shares in size and growth by group, region, and Major economies

	Period 1989–1995								Period 1995–2000							
		Sources of Growth (% ppa)								Sources of Growth (% ppa)						
		Capital Input			Labor Input					Capital Input			Labor Input			
Group Summaries	GDP Growth	All	ICT	Non-ICT	All	Quality	Hours	TFP	GDP Growth	All	ICT	Non-ICT	All	Quality	Hours	TFP
World (122 Economies)	**2.34**	**1.34**	**0.29**	**1.05**	**0.70**	**0.36**	**0.34**	**0.29**	**3.61**	**1.80**	**0.57**	**1.23**	**1.11**	**0.30**	**0.81**	**0.70**
G7	2.15	1.33	0.39	0.95	0.44	0.33	0.11	0.38	3.11	1.85	0.78	1.07	0.92	0.27	0.65	0.34
Developing Asia	7.54	2.83	0.19	2.64	1.50	0.44	1.06	3.21	5.68	2.91	0.33	2.58	1.28	0.39	0.88	1.48
Non-G7	2.13	1.10	0.34	0.76	0.66	0.41	0.26	0.36	3.67	1.67	0.65	1.02	1.56	0.26	1.30	0.43
Latin America	2.87	0.67	0.13	0.54	1.58	0.41	1.17	0.62	2.92	1.25	0.27	0.98	1.65	0.37	1.28	0.02
Eastern Europe	−6.69	0.08	0.10	−0.02	−1.22	0.12	−1.34	−5.55	2.23	−0.35	0.23	−0.58	−0.27	0.10	−0.37	2.85
Sub-Saharan Africa	1.80	0.52	0.16	0.36	2.56	0.61	1.95	−1.28	3.47	1.06	0.32	0.73	2.35	0.48	1.87	0.06
N. Africa & M. East	4.03	0.95	0.11	0.84	2.61	0.64	1.97	0.47	3.97	1.24	0.18	1.05	2.06	0.54	1.52	0.68
	Period 2000–2004								Period 2004–2008							
		Sources of Growth (% ppa)								Sources of Growth (% ppa)						
		Capital Input			Labor Input					Capital Input			Labor Input			
Group Summaries	GDP Growth	All	ICT	Non-ICT	All	Quality	Hours	TFP	GDP Growth	All	ICT	Non-ICT	All	Quality	Hours	TFP
World (122 Economies)	**3.25**	**1.35**	**0.42**	**0.93**	**0.68**	**0.29**	**0.38**	**1.22**	**4.43**	**1.82**	**0.42**	**1.40**	**0.96**	**0.22**	**0.74**	**1.65**
G7	1.74	1.05	0.45	0.60	0.19	0.31	−0.12	0.50	1.83	1.10	0.36	0.73	0.45	0.17	0.28	0.28
Developing Asia	6.57	2.66	0.44	2.22	1.27	0.32	0.95	2.64	8.22	3.32	0.50	2.82	1.23	0.34	0.89	3.68
Non-G7	2.32	1.40	0.46	0.94	0.91	0.29	0.61	0.02	2.67	1.59	0.44	1.14	1.26	0.21	1.06	−0.18
Latin America	2.20	0.87	0.28	0.59	1.36	0.19	1.16	−0.03	5.27	1.67	0.39	1.28	1.91	0.19	1.72	1.69
Eastern Europe	5.48	0.11	0.33	−0.22	0.17	0.22	−0.05	5.20	6.57	1.10	0.38	0.72	0.91	0.19	0.72	4.55
Sub-Saharan Africa	4.22	1.55	0.42	1.12	1.80	0.28	1.52	0.88	5.69	2.65	0.84	1.81	1.78	0.29	1.49	1.26
N. Africa & M. East	4.40	1.10	0.25	0.85	1.74	0.25	1.50	1.56	7.86	2.44	0.34	2.10	1.81	0.19	1.62	3.60

Continued.

Table 6. Continued

G7 (Economy)

Period 1989–1995

Economy	GDP Growth	Sources of Growth (% ppa)						
		Capital Input			Labor Input			
		All	ICT	Non-ICT	All	Quality	Hours	TFP
Canada	1.69	1.27	0.42	0.85	0.40	0.31	0.10	0.02
France	1.41	0.70	0.17	0.54	0.41	0.57	–0.16	0.31
Germany	2.62	1.00	0.26	0.74	0.29	0.04	0.25	1.32
Italy	1.40	0.70	0.15	0.54	–0.26	0.10	–0.36	0.97
Japan	2.16	2.08	0.27	1.81	0.00	0.28	–0.28	0.08
United Kingdom	1.77	0.96	0.45	0.51	–0.25	0.57	–0.82	1.07
United States	2.38	1.39	0.53	0.87	0.89	0.39	0.49	0.10
All Group	**2.15**	**1.33**	**0.39**	**0.95**	**0.44**	**0.33**	**0.11**	**0.38**

Period 1995–2000

Economy	GDP Growth	Sources of Growth (% ppa)						
		Capital Input			Labor Input			
		All	ICT	Non-ICT	All	Quality	Hours	TFP
Canada	4.23	1.81	0.69	1.11	1.34	0.13	1.21	1.08
France	2.66	0.91	0.36	0.55	0.92	0.48	0.43	0.83
Germany	1.96	1.37	0.50	0.87	–0.11	–0.10	0.00	0.70
Italy	1.77	1.06	0.38	0.68	0.83	0.17	0.66	–0.12
Japan	1.21	1.26	0.40	0.86	–0.09	0.50	–0.60	0.04
United Kingdom	3.16	1.67	0.97	0.70	1.18	0.50	0.68	0.31
United States	4.21	2.47	1.08	1.39	1.46	0.23	1.23	0.29
All Group	**3.11**	**1.85**	**0.78**	**1.07**	**0.92**	**0.27**	**0.65**	**0.34**

Period 2000–2004

Economy	GDP Growth	Sources of Growth (% ppa)						
		Capital Input			Labor Input			
		All	ICT	Non-ICT	All	Quality	Hours	TFP
Canada	2.56	1.43	0.38	1.04	1.04	0.07	0.97	0.09
France	1.51	0.85	0.26	0.59	0.35	0.26	0.09	0.31
Germany	0.69	0.71	0.28	0.42	–0.13	0.35	–0.48	0.11
Italy	0.94	0.96	0.17	0.78	0.66	0.07	0.59	–0.68
Japan	0.98	0.92	0.26	0.65	–0.06	0.45	–0.50	0.12
United Kingdom	2.30	1.02	0.56	0.47	1.09	0.50	0.59	0.18
United States	2.21	1.17	0.60	0.58	0.03	0.30	–0.27	1.01
All Group	**1.74**	**1.05**	**0.45**	**0.60**	**0.19**	**0.31**	**–0.12**	**0.50**

Period 2004–2008

Economy	GDP Growth	Sources of Growth (% ppa)						
		Capital Input			Labor Input			
		All	ICT	Non-ICT	All	Quality	Hours	TFP
Canada	2.16	2.00	0.49	1.51	0.94	0.05	0.89	–0.79
France	1.70	0.94	0.20	0.74	0.52	0.12	0.40	0.24
Germany	2.00	0.87	0.35	0.51	0.22	–0.21	0.43	0.91
Italy	0.86	0.77	0.16	0.61	0.56	0.12	0.44	–0.47
Japan	1.29	0.73	0.20	0.53	0.08	0.21	–0.13	0.48
United Kingdom	2.08	1.10	0.37	0.73	0.47	0.17	0.30	0.51
United States	2.05	1.25	0.46	0.79	0.55	0.27	0.28	0.25
All Group	**1.83**	**1.10**	**0.36**	**0.73**	**0.45**	**0.17**	**0.28**	**0.28**

Seven Major Developing and Transition Economies

Period 1989–1995

		Sources of Growth (% ppa)						
		Capital Input			Labor Input			
Economy	GDP Growth	All	ICT	Non-ICT	All	Quality	Hours	TFP
Brazil	1.71	0.43	0.11	0.32	0.95	0.43	0.52	0.33
China	10.26	3.20	0.14	3.05	1.32	0.50	0.82	5.75
India	5.03	1.94	0.08	1.85	1.86	0.48	1.39	1.23
Indonesia	7.75	2.91	0.16	2.75	1.43	0.47	0.96	3.41
Mexico	2.09	1.01	0.15	0.86	1.84	0.41	1.43	−0.76
Russia	−8.44	0.44	0.08	0.35	−1.44	−0.08	−1.36	−7.44
South Korea	7.73	3.88	0.42	3.47	1.65	0.34	1.31	2.20
All Group	**3.00**	**1.80**	**0.14**	**1.66**	**0.86**	**0.34**	**0.52**	**0.34**

Period 1995–2000

		Sources of Growth (% ppa)						
		Capital Input			Labor Input			
Economy	GDP Growth	All	ICT	Non-ICT	All	Quality	Hours	TFP
Brazil	1.97	0.93	0.31	0.62	1.11	0.40	0.71	−0.06
China	8.27	3.87	0.37	3.50	1.18	0.43	0.75	3.22
India	5.67	2.27	0.18	2.08	1.52	0.45	1.06	1.89
Indonesia	0.70	2.08	0.13	1.95	1.95	0.44	1.50	−3.33
Mexico	5.31	1.18	0.17	1.01	2.42	0.34	2.08	1.71
Russia	1.60	−1.42	0.12	−1.54	−0.52	−0.14	−0.38	3.54
South Korea	4.28	2.76	0.53	2.23	0.06	0.27	−0.21	1.46
All Group	**4.98**	**2.04**	**0.28**	**1.76**	**1.09**	**0.34**	**0.75**	**1.86**

Period 2000–2004

		Sources of Growth (% ppa)						
		Capital Input			Labor Input			
Economy	GDP Growth	All	ICT	Non-ICT	All	Quality	Hours	TFP
Brazil	2.68	0.63	0.39	0.24	1.99	0.21	1.78	0.06
China	8.96	3.91	0.55	3.37	1.18	0.50	0.68	3.86
India	6.20	2.37	0.32	2.05	1.80	0.20	1.60	2.03
Indonesia	4.39	1.08	0.17	0.91	0.77	0.08	0.69	2.54
Mexico	1.53	1.37	0.16	1.21	0.87	0.21	0.67	−0.71
Russia	5.90	−0.76	0.25	−1.00	0.64	0.17	0.47	6.01
South Korea	4.54	1.99	0.50	1.50	0.33	0.06	0.27	2.22
All Group	**6.03**	**2.12**	**0.39**	**1.73**	**1.20**	**0.29**	**0.91**	**2.71**

Period 2004–2008

		Sources of Growth (% ppa)						
		Capital Input			Labor Input			
Economy	GDP Growth	All	ICT	Non-ICT	All	Quality	Hours	TFP
Brazil	4.35	1.24	0.55	0.70	1.67	0.21	1.46	1.44
China	10.43	4.38	0.58	3.80	0.99	0.50	0.50	5.06
India	8.42	3.75	0.47	3.28	1.79	0.20	1.59	2.89
Indonesia	5.72	1.78	0.29	1.49	1.55	0.08	1.47	2.39
Mexico	3.15	1.58	0.16	1.42	2.00	0.21	1.79	−0.43
Russia	7.04	0.52	0.35	0.17	0.61	0.17	0.44	5.91
South Korea	5.04	1.80	0.47	1.33	−0.24	0.06	−0.30	3.48
All Group	**7.78**	**2.92**	**0.47**	**2.45**	**1.18**	**0.30**	**0.88**	**3.68**

after 1995. In Table 6 Jorgenson and Khuong Vu (2009) have shown that the pattern of IT investment in the G7 and Non-G7 industrialized economies mirrors that in the U.S., but on a substantially reduced scale. Beginning from much lower levels in 1989–1995, the contribution of IT investment in Developing Asia after 2000 is comparable to G7 levels.

The transformation of the U.S. economy by the new wave of innovation has counterparts, especially in the relatively small Scandinavian economies, Ireland, and Israel. However, van Ark, O'Mahony, and Timmer (2008) show that the acceleration of U.S. innovation has been accompanied by a marked deceleration in productivity growth in the four major economies of the European Union – France, Germany, Italy, and the U.K. – homes to many of the leading competitors for U.S. multi-nationals. Applications of information technology have encountered formidable obstacles in these economies due to deeply entrenched policies of market and job protection.

Unfortunately, policies of market and job protection are not limited to industrialized economies. The contribution of investment in information technology equipment and software has risen steadily in Brazil, China, India, Russia, and South Korea, while Indonesia and Mexico have been left behind. Brazil, Indonesia, and Mexico give little evidence of sustained innovation, while China and India are slowly catching up to other Asian economies. Russia is only now fully recovered from the economic collapse of the 1990s and South Korea's rate of productivity growth has declined since the Asian financial crisis.

The production of information technology equipment and software has proved to be highly volatile. The great IT investment boom of 1995–2000 was followed by the dot-com crash and the slow and painful recovery of 2000–2007. The boom of 1995–2000 was generated by an unsustainable deluge of innovation in the production of semiconductors and semiconductor-intensive computers. By contrast the wave of innovation that followed in 2000–2007 has spread across a broader spectrum of IT-using industries. This has created a diversified advance in the applications of information technology.

Erik Brynjolfsson and Adam Saunders (2009) survey innovations based on applications of IT. Highly volatile IT production is giving way to a broadly diversified advance in IT applications. These spawn innovations in more than forty percent of the U.S. economy, but well under half this proportion of the world economy. Globalization is creating enormous new opportunities for the application of information technology. The source of competitiveness in the world economy will be the successful exploitation of IT-based business models, systems, and organizational structures.

Successful applications of information technology require new organizational structures to manage the steady procession of new generations of equipment and software. These organizational structures themselves rapidly become antiquated, so that executive-level management of information technology-based businesses must direct a continuous process of restructuring. Business systems have become imbedded in software that requires incessant updating as business needs evolve.

Globalization through trade in goods, especially manufactured goods, agricultural products, and natural resource products like oil and gas, has advanced with the opening of the major emerging economies of Brazil, China, India, and Russia. However, globalization of services is only beginning, accompanied by a chorus of protectionist attacks on "outsourcing" and "offshoring". The European Union, founded on the principle of a single market, has failed to create a single market in trade and services, which make up 70–80 percent of activity in most industrialized economies. A central feature of the U.S. economy is the gradual extension of a single market in trade and services through broadening the scope of application of the Interstate Commerce Clause of the U.S. Constitution of 1787.

The removal of impediments to applications of information technology is opening new business prospects on a daily basis, not only in industrialized economies, but in developing and transition economies like Brazil, China, India, and Russia. Some of these economies are already major participants in information technology production. However, the arena for competition has shifted to IT-using trade and service industries. International competitiveness in the world economy will be rooted in the IT-based business models, systems, and organizational structures that emerged phoenix-like from the ruins of the dot-com crash of 2000.

Conclusion

The new framework for productivity measurement that grew out of the insights of

Schultz (1962) reveals that innovation accounts for most of the growth of U.S. agricultural output with only a minor role for information technology. Innovation also accounts for the bulk of output growth in the computer industry, which is highly IT-intensive. However, replication of established technologies through growth of capital and labor inputs, recently through massive investments in IT hardware and software, explains by far the largest proportion of U.S. economic growth. International productivity comparisons reveal similar patterns for the world economy, its major regions, and leading industrialized, developing, and emerging economies. Studies are now underway to extend these comparisons to individual industries, such as agriculture and computers.

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