# NEW DATA ON U.S. PRODUCTIVITY GROWTH BY INDUSTRY

by

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## ABSTRACT

The rapid productivity growth in the U.S. during the Information Age, prior to the dot-com bust in 2000, and the large contribution of the IT producing sector, is now well known. What is less known are the sources of the surprising rapid TFP growth post 2000, during a period that included a recession and a major slowdown of investment. We construct an account of U.S. economic growth by aggregating over detailed industries using a new data set based on the NAICS classification. Our methodology distinguishes the contribution of TFP growth at the industry level to aggregate TFP from the effects of reallocation of capital and labor across industries. We find that, post 2000, the deceleration of TFP growth in the IT producing sector was offset by the acceleration in the IT-using sector, and would have kept aggregate TFP growth at the rapid rate of the 1995-2000 period except for the reallocation effects. For aggregate GDP, the contributions to the growth rate of 2.8% during 2000-07 were: capital input (1.7 percentage points), labor input (0.4) and TFP (0.7).

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## Introduction

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 great preponderance of economic growth in the U.S. involves the replication of existing technologies through investment in equipment and software and expansion of the labor force. Replication generates economic growth with no increase in productivity. Productivity growth is the key economic indicator of innovation. This innovation accounts for less than twelve percent of U.S. economic growth, despite its importance in industries like computers and agriculture. Although innovation contributes only a modest portion of growth, this is vital to long-term gains in the American 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 very modest impact over the intermediate term of ten years. However, the long-run growth of the

[1] We thank Ankur Patel for research assistance in preparing the data.

economy depends critically on the performance of a relatively small number of sectors, such as agriculture and computers, where innovation takes place.

The purpose of this paper is to present a new data set on U.S. productivity growth by industry. This data set covers 70 industries for the period 1960-2007 and uses the North American Industry Classification System (NAICS). Previous industry-level data sets on U.S. productivity provided by Jorgenson, Gollop, and Fraumeni (1987) and Jorgenson, Ho, and Stiroh (2005) have used the Standard Industrial Classification (SIC). The U.S. statistical system has shifted gradually to NAICS, beginning with the Business Census of 1997. The national accounts shifted to NAICS with the 2003 Comprehensive Revision of the National Income and Product Accounts.

An important advantage of NAICS over the SIC is the greater detail available on the service industries that make up a growing proportion of the U.S. economy. Jorgenson, Ho, Samuels, and Stiroh (2007) have shown that U.S. productivity growth has shifted to the service industries since 2000, especially those that make intensive use of information technology. NAICS also provides more detail on industries that produce information technology hardware, software, and services. The service-producing industries, information and data processing services and computer systems design and related services, are growing in importance, relative to software and the IT hardware manufacturing industries – computer and peripheral equipment, communications equipment, and semiconductor and other electronic components.

This paper begins with a brief summary of the methodology for productivity measurement. The traditional approach of Kuznets (1971) and Solow (1970) has been superseded by the new framework presented in 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 are based on the production accounts constructed by Jorgenson, Gollop, and Fraumeni (1987). These accounts were updated and revised to incorporate investments in information technology hardware and software by Jorgenson, Ho, and Stiroh (2005). The EU (European Union) KLEMS (capital, labor, energy, materials, and services) study, described by O'Mahony and 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 the U.S., based on the methodology 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 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 information and computing. The "killer application" of the new framework for productivity measurement is the impact of investment in IT equipment and software on economic growth. Research on the impact of this investment in 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. They have measured output and productivity for the IT-producing industries. They have divided the remaining industries between the IT-using industries, those that are particularly intensive in the utilization of information technology equipment and software, and the Non-IT industries. However, the IT-producing industries were limited to IT hardware and software and did not include IT services. Furthermore, the definition of the IT-using industries was based on the intensity of IT capital input, relative to total capital input. Again, the role of the IT service industries was not identified. The final section sums up the paper.

**The New Framework for Productivity Measurement.**

The most serious challenge to the traditional approach to productivity measurement of Kuznets (1971) and Solow (1970) was mounted by Jorgenson and Griliches (1967) in "The Explanation of Productivity Change". Jorgenson and Griliches departed radically from the measurement conventions of the traditional approach. They replaced NNP with GNP as a measure of output and introduced constant quality indexes for both capital and labor inputs.

The key idea underlying the *constant quality index of labor input* was to distinguish among different types of labor inputs. Jorgenson and Griliches 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 had modeled substitution between capital and labor inputs, Jorgenson and Griliches 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 productivity growth. 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).

Jorgenson and Griliches 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, they 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 productivity growth.

Jorgenson and Griliches employed a model of capital as a factor of production introduced by Jorgenson (1963) in "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, Jorgenson and Griliches replaced the aggregate production function employed by Kuznets and Solow with the *production possibility frontier* introduced in Jorgenson (1966) in "The Embodiment Hypothesis". This allowed for joint production of consumption and investment goods from capital and labor services. This captures the fact that systems of national accounts distinguish between outputs of consumption, investment, and other goods and services. Each of these is associated with a price deflator that is specific to the category of output.

Jorgenson used the production possibility frontier to generalize Solow's (1960) concept of embodied technical change, showing that productivity growth could be interpreted, equivalently, as "embodied" in investment or "disembodied". Jorgenson and Griliches (1967) 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.

Oulton (2007) demonstrated that Solow's model of embodied technical change is a special case of Jorgenson's (1966) model. He also compared the empirical results of Solow's one-sector model and a two-sector model with outputs of consumption and investment goods. Greenwood and Krussell (2007) employed 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 the national accounting conventions that provide separate deflators for consumption, investment, and other outputs.

Jorgenson and Griliches showed that changes in the quality of capital and labor inputs and the quality of investment goods explained most of the Solow residual. They 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.[2] 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.

**Official Statistics on Productivity.**

The final blow to the traditional framework for productivity measurement of Kuznets (1971) and Solow (1970) was administered by the Panel to Review Productivity Statistics of the National Research Council (1979). The Rees Report, *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.

[2]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.

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 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.

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. This index was included in the BLS measure of output, completing the displacement of the traditional framework of economic measurement by the conventions employed by Jorgenson and Griliches (2007).

Jorgenson and 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, as well as productivity. The incorporation of the price and quantity of capital services into the United Nations' *System of National Accounts 2008* (U.N. 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* (U.N. 2009, 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 and productivity 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 U.S. Secretary of Commerce (2008, page 8) 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.

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 Harper, Moulton, Rosenthal, and 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.**

A complete system of industry-level production accounts for the U.S. economy was constructed by Gollop and Jorgenson (1980) and Jorgenson, Gollop, and Fraumeni (1987), using the SIC. 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, Gollop, and Fraumeni (1987, Chapter 5, pp. 149-182) and Jorgenson, Ho, and Stiroh (2005, Chapter 4, pp. 87-146).

The approach to growth accounting presented by Jorgenson, Gollop and Fraumeni (1987) 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 a 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, Powers, and 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 Lawson, Moyer, Okubo and Planting (2006), and Moyer, Reinsdorf, and Yuskavage (2006). Donahoe, Morgan, Muck, and Stewart (2010) present data for the fully integrated system for 1998-2008 on a NAICS basis.

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*, present industry-level data on productivity. These data have made possible the international comparisons of patterns of structural change presented by Jorgenson and Timmer (2009). 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**

We provide NAICS-based estimates of output and productivity for the IT-producing industries listed in Table 1. These include software and the IT-services industries – information and data processing and computer systems design – as well as the IT-producing hardware industries – computers, communications equipment, and semiconductors. The information and data processing industry provides computation, communications, and storage services that compete directly with the services provided through investment in IT equipment and software. The computer systems design industry provides the services necessary to integrate this investment into business operations.

In our earlier work using the SIC (Jorgenson, Ho and Stiroh 2005, Jorgenson et al 2007), we have defined IT intensity at the industry level as the share of IT-capital input in total capital input of that industry. The NAICS data here introduces a level of detail not seen in the SIC system – intermediate inputs from the IT-services group, $A_{IT,j}$. We therefore define the IT-intensity index for industry *j* as the share of capital input including intermediate IT-services:

$$(1) \qquad III_j = \frac{K_{jT}^{IT} + A_{IT,j,T}}{K_{jT} + A_{IT,j,T}}; \quad T=2005$$

where $K_{jT}^{IT}$ is the IT-capital input and $K_{jT}$ is the total capital input[3].

These intensities are given in Tables 1 and 2. We define the IT-using industries as those with *III* more than the median share of 15.4 percent in 2005. The IT-intensive using industries are listed in Table 1 and include Wholesale and Retail Trade as well as many of the major service industries. The Non-IT industries are given in Table 2 and include the resource-based industries, agriculture and mining, as well as many of the major manufacturing industries. We present NAICS-based estimates of output and productivity for these industries as well.

We initially focus on the IT-producing sectors. The distinctive feature of IT equipment and software is the rapid decline in prices. Figure 1 shows that computers and semiconductors have had rapidly defining prices, relative to the GDP deflator, since the commercialization of the electronic computer in 1959. The decline accelerated with the switch from vacuum tubes to semiconductors around 1970. Software publishing has had a rapid rate of decline from the same time, but this slowed after 1990. The IT-services sectors have had declining prices, relative to the GDP deflator, only since 2000.

[3] IT intermediate services are the intermediate purchases from Information and data processing (industry 38), Computer systems design (45) and Software publishing (68).

Jorgenson (2001) has shown that the acceleration in the rate of decline of the prices of computers and semiconductors around 1995 is the source of the investment boom in IT hardware and software during the period 1995-2000. He has attributed the acceleration in the price decline of computers and semiconductors with a shift in the product cycle for semiconductors from three years to two years. We note that the rate of decline of semiconductor prices has slowed since 2000, while the accelerated decline in computer prices that began in 1995 has continued.

Figure 2 presents the shares of IT-producing industries in the U.S. GDP on an annual basis since 1960. The overall share has increased substantially from around one percent of the GDP to just under three percent at the end of the period 1960-2007. However, the IT investment boom of 1995-2000 can now be identified as an unsustainable "bubble" that burst in 2000. The share of IT software and hardware – computers, semiconductors, and telecommunications equipment has dropped substantially since 2000 and shows no signs of revival. The IT service industries, especially computer systems design, grew substantially during the IT investment boom of the 1990's and have resumed the growth that was interrupted by the dot-com crash of 2000.

We define the contribution of an industry to U.S. economic growth as the growth rate of real value added in the industry, weighted by the share of the industry in the GDP. Figure 3 gives the contributions of the six IT-producing sectors to economic growth during the period 1960-2007. Computers, semiconductors, and software have grown at double-digit rates throughout this period. The contributions of these industries to U.S. economic growth were far out of proportion to their relatively modest shares in value added, for the 1960-07 period they contributed 0.31 percentage points of the aggregate growth of 3.45 percent per year. The technology employed in communications equipment has some affinities with computer technology, but the growth rate of this industry is much below that of computers and its contribution to economic growth is relatively modest (the darkest portion in the bars in Figure 3).

The contributions of IT hardware and software peaked during the IT investment boom from 1995-2000, but these contributions did not prove to be sustainable and have fallen below the average contributions of 1960-1995. Software contribution remains a bit above the average of the earlier period, but the contribution of semiconductors is considerably below. The contribution of computer systems design also peaked during the boom, but this contribution is well above the 1960-1995 average. The contribution of information and data processing has grown steadily throughout the period 1960-2007.

In our methodology 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 past investment in IT equipment and software to economic growth. This contribution is the relative share of IT equipment and software capital input in the value of aggregate output (GDP), multiplied by the rate of growth of IT capital inputs (in Table 3 this contribution is the row marked "IT Capital" while Table 4 gives the growth rate and shares). 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 aggregate 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. In Table 3 we can see that labor input contributed 0.97 percentage points to growth during 1960-2007, and of that, college-educated labor contributed 0.58 percentage points.

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. 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 Easterly (2001) and is listed as one of the "stylized facts" about economic growth by King and Rebelo (1999). However, Table 3 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 preponderance 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 3 (second last column) 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 in this period of unusually low unemployment. 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, 0.62 versus 0.61 percentage points.

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. In order to analyze this in more detail, we utilize the production possibility frontier of Jorgenson, Gollop, and Fraumeni (1987, Ch. 9, pp. 301-342) and Jorgenson, Ho, and Stiroh (2005, Ch. 8, pp. 361-416). This gives the relationship between aggregate productivity growth and productivity growth at the industry level. The growth rate of aggregate productivity includes a weighted average of industry productivity growth rates, using an ingenious weighting scheme originated by Domar (1961).

In the Domar weighting scheme the productivity growth rate of each industry is weighted by the ratio of the industry’s gross output to aggregate value added. A distinctive feature of Domar weights is that they sum to more than one, reflecting the fact that an increase in the rate of growth of the industry’s productivity has two effects. The first is a direct effect on the industry’s output and the second an indirect effect via the output delivered to other industries as intermediate inputs.

The rate of growth of aggregate productivity also depends on the reallocations of capital and labor inputs among industries. The rate of aggregate productivity growth exceeds the Domar-weighted sum of industry productivity growth rates when these reallocations are positive. This occurs when capital and labor inputs are paid different prices in different industries and industries with higher prices have more rapid growth rates of the inputs. Under this assumption aggregate capital and labor inputs grow more slowly than the Domar-weighted averages of industry capital and labor input growth rates.

Table 5 gives the decomposition of the rate of growth of productivity presented in Table 3 above. The Domar-weighted sum of industry productivity growth rates for the period 1960-2007 is

0.33 percent and the aggregate productivity growth rate is 0.41 percent. The difference between the two is due to a positive reallocation of capital input of 0.10 and a negative reallocation of labor input of 0.02 percent. We conclude that the industry-level rates of productivity growth are the main sources of aggregate productivity growth over long periods of time.

Table 5 shows that the IT-producing industries predominate in aggregate productivity growth, the IT-using industries are second in importance, and the Non-IT industries have a small negative contribution to aggregate productivity growth. 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 these industries accounted for 60 percent of the substantially increased contribution of innovation. After the dot-com crash this contribution receded toward the long term average of 1960-1995. How, then, did rapid innovation in the aggregate continue after 2000?

Table 5 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.

Figure 4 provides additional detail on innovation in the IT-producing industries. Semiconductors, computers, and software dominate innovation during the period 1960-2007. Innovation in information and data processing is slightly positive during this period, while innovation in computer systems and design is slightly negative. For the period 1960-1995 innovation is concentrated on the IT hardware and software industries. From 1995-2000 this innovation greatly increased, while productivity growth in the IT services industries was negative. For the period 2000-2007 innovation was substantial in the IT-services industries, but innovation diminished sharply in the IT hardware and software industries.

The locus of U.S. innovation is revealed by the contribution of productivity growth in the industries listed in Tables 6 and 7 to U.S. economic growth during 1960-2007. Figures 5 and 6 give a rank ordering of industries by contributions to value added and productivity. 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 IBM and Intel have continuing product and process innovations. 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. 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.

**Conclusion**

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.

Brynjolfsson and Saunders (2009) survey innovations based on applications of IT. Highly volatile IT production is giving way to a broadly diversified advance in IT applications. 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.

The new framework for productivity measurement 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.

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**Table 1: IT-Related Industries**

| IT-Producing Industries | IT share 2005 |
|---|---|
| Computer and peripheral equipment mfg | 0.3571 |
| Communications equipment mfg | 0.3868 |
| Semiconductor and other electronic component mfg | 0.4105 |
| Software publishing | 0.4421 |
| Information and data processing services | 0.7929 |
| Computer systems design and related services | 0.9497 |

| IT-intensive Using Industries | |
|---|---|
| Construction | 0.2271 |
| Machinery | 0.3387 |
| Motor vehicles bodies and trailers and parts | 0.2428 |
| Other transportation equipment | 0.3053 |
| Miscellaneous mfg | 0.1631 |
| Printing and related support activities | 0.2018 |
| Wholesale Trade | 0.2186 |
| Retail Trade | 0.1572 |
| Air transportation | 0.6796 |
| Water transportation | 0.4788 |
| Transit and ground passenger transportation | 0.3182 |
| Pipeline transportation | 0.4168 |
| Other transportation and support activities | 0.1789 |
| Broadcasting and telecommunications | 0.5695 |
| Fed. Res. banks, credit intermediation | 0.2226 |
| Securities commodity contracts and investments | 0.8461 |
| Insurance carriers and related activities | 0.3161 |
| Rental & leasing, and lessors of intangible assets | 0.3217 |
| Legal services | 0.3382 |
| Misc. professional scientific and technical services | 0.6331 |
| Management of companies and enterprises | 0.5426 |
| Administrative and support services | 0.5017 |
| Waste management and remediation services | 0.1759 |
| Educational services | 0.5468 |
| Hospitals Nursing and residential care facilities | 0.3715 |
| Social assistance | 0.2125 |
| Performing arts, spectator sports & related activities | 0.2291 |
| Federal General government | 0.3046 |
| S&L General Government | 0.1672 |
| Other electronic products | 0.4445 |
| Newspaper; periodical; book publishers | 0.5459 |

Notes: IT-Using industries are those with more than the median share of 15.4 percent for III in 2005.

**Table 2: Non IT-intensive Using Industries**

| non IT-intensive Using Industries | IT share 2005 |
|---|---|
| Farms | 0.0139 |
| Forestry  fishing  and related activities | 0.0367 |
| Oil and gas extraction | 0.0312 |
| Mining  except oil and gas | 0.1030 |
| Support activities for mining | 0.1078 |
| Utilities | 0.0737 |
| Wood products | 0.0906 |
| Nonmetallic mineral products | 0.1022 |
| Primary metals | 0.0887 |
| Fabricated metal products | 0.1354 |
| Electrical equipment appliances and components | 0.1096 |
| Furniture and related products | 0.1447 |
| Food and beverage and tobacco products | 0.1145 |
| Textile mills and textile product mills | 0.0967 |
| Apparel and leather and allied products | 0.0921 |
| Paper products | 0.1200 |
| Petroleum and coal products | 0.0895 |
| Chemical products | 0.1406 |
| Plastics and rubber products | 0.0857 |
| Rail transportation | 0.0820 |
| Truck transportation | 0.1544 |
| Warehousing and storage | 0.1435 |
| Motion picture and sound recording industries | 0.1376 |
| Funds  trusts  and other financial vehicles | 0.0769 |
| Ambulatory health care services | 0.1203 |
| Amusements gambling and recreation industries | 0.0772 |
| Accommodation | 0.0680 |
| Food services and drinking places | 0.1183 |
| Other services except government | 0.1501 |
| Federal Government enterprises | 0.1116 |
| S&L Government enterprises | 0.1227 |
| Real estate | 0.0142 |

Notes:  IT-Using industries are those with more than the median share of 15.4 percent for III in 2005.

**Table 3: Growth in Aggregate Value-Added and the Sources of Growth**

| | 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 | 1.75 | 1.77 | 2.31 | 1.27 | 0.55 | -0.50 |
| Non-IT Industries | 1.39 | 1.41 | 1.40 | 1.24 | -0.02 | -0.18 |
| 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 1 and Table 2.

**Table 4: Growth and Shares of Aggregate Variables**

| | 1960-2007 | 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 | 3.47 | 3.56 | 4.39 | 2.39 | 0.83 |
| Non-IT Industries | 2.92 | 2.90 | 3.16 | 2.81 | 0.26 |
| 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 | 50.9 | 50.1 | 52.7 | 53.2 | 2.5 |
| Non-IT Industries | 47.3 | 48.4 | 44.4 | 44.0 | -4.0 |
| 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 percentages. Shares are the mean two-period average for each period in percentages.

**Table 5: Decomposition of Aggregate Productivity Growth**

| | 1960-2007 | 1960-1995 | 1995-2000 | 2000-2007 | 1995-2000 less 1960-1995 | 1995-2007 less 1960-1995 |
|---|---|---|---|---|---|---|
| Aggregate TFP | 0.41 | 0.28 | 0.90 | 0.72 | 0.62 | 0.44 |
| 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 | 0.18 | 0.15 | 0.10 | 0.35 | -0.05 | 0.20 |
| Non-IT Industries | -0.07 | -0.10 | 0.04 | 0.03 | 0.14 | 0.13 |
| 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 percentages. The domar weight is the ratio of industry output to aggregate value added.

**Table 6: Industry Contributions to Aggregate Value-Added and TFP Growth, 1960-2007**

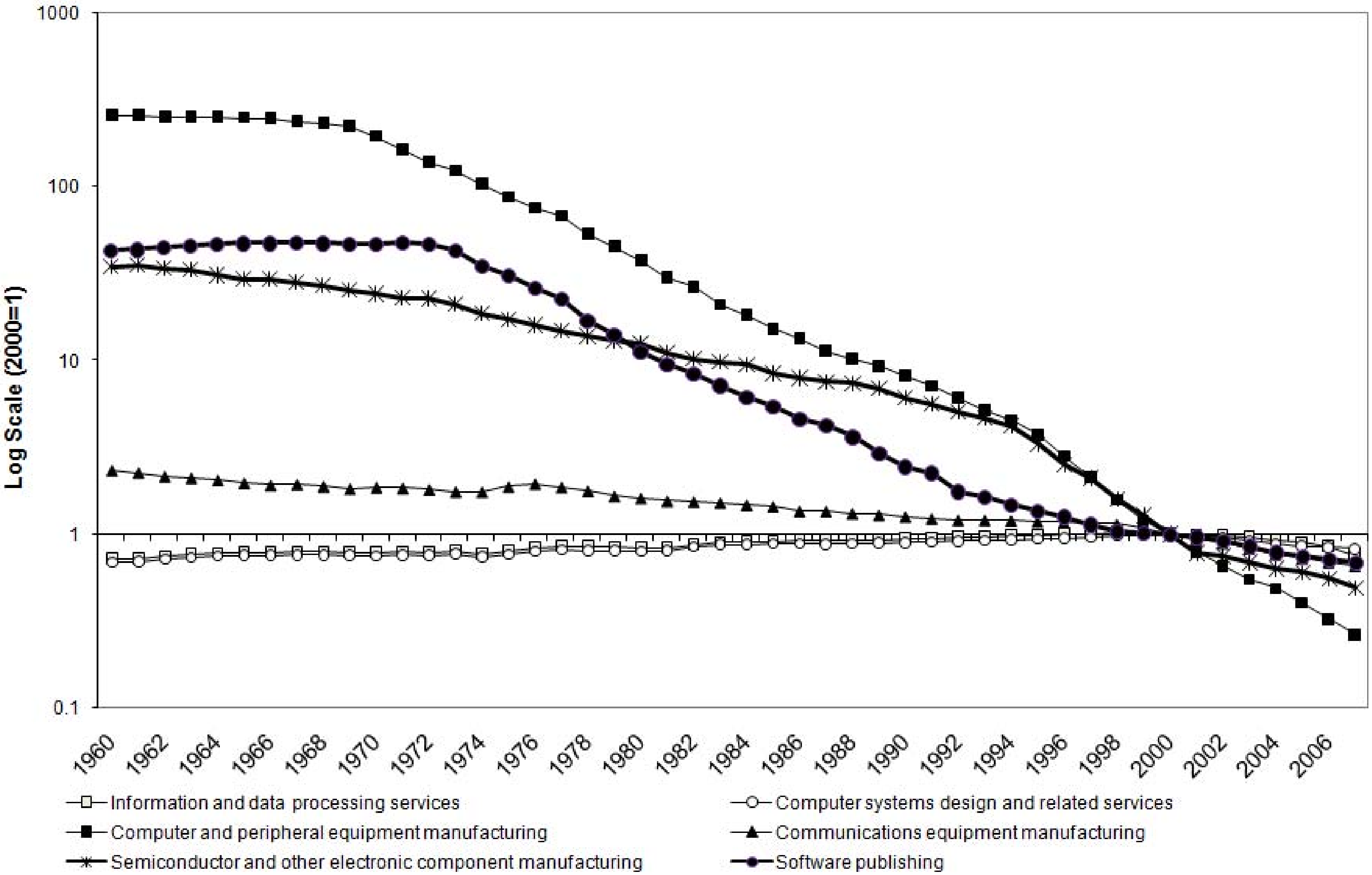
| | Value-Added | | | Productivity | | |
|---|---|---|---|---|---|---|
| | V-A Weight | V-A Growth | Contribution to Aggregate V-A | Domar Weight | TFP Growth | Contribution to Aggregate TFP |
| Farms | 0.018 | 2.59 | 0.036 | 0.042 | 1.40 | 0.050 |
| Forestry fishing and related activities | 0.003 | 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 vehicles bodies and trailers and parts | 0.014 | 2.41 | 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 |
| Apparel 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 and related activities | 0.025 | 3.82 | 0.091 | 0.036 | -1.57 | -0.055 |
| Securities commodity contracts and investments | 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 intangible assets | 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 services | 0.005 | 7.45 | 0.039 | 0.006 | -1.60 | -0.004 |
| Miscellaneous professional scientific and technical services | 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 services | 0.015 | 5.21 | 0.075 | 0.024 | -0.08 | 0.001 |
| Waste management and remediation services | 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 facilities | 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 and related activities | 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 component manufacturing | 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 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 7: 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 | 0.000 |
| 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 and related activitie | 0.116 | 0.051 | 0.065 | 0.030 | 0.020 | 0.011 |
| Securities commodity contracts and investments | 0.012 | 0.011 | 0.001 | 0.026 | 0.022 | 0.004 |
| 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 intangible assets | 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 services | 0.010 | 0.009 | 0.001 | 0.033 | 0.024 | 0.010 |
| Miscellaneous professional scientific and technical services | 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 services | 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 facilities | 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 and related activities | 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 component manufacturing | 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 |

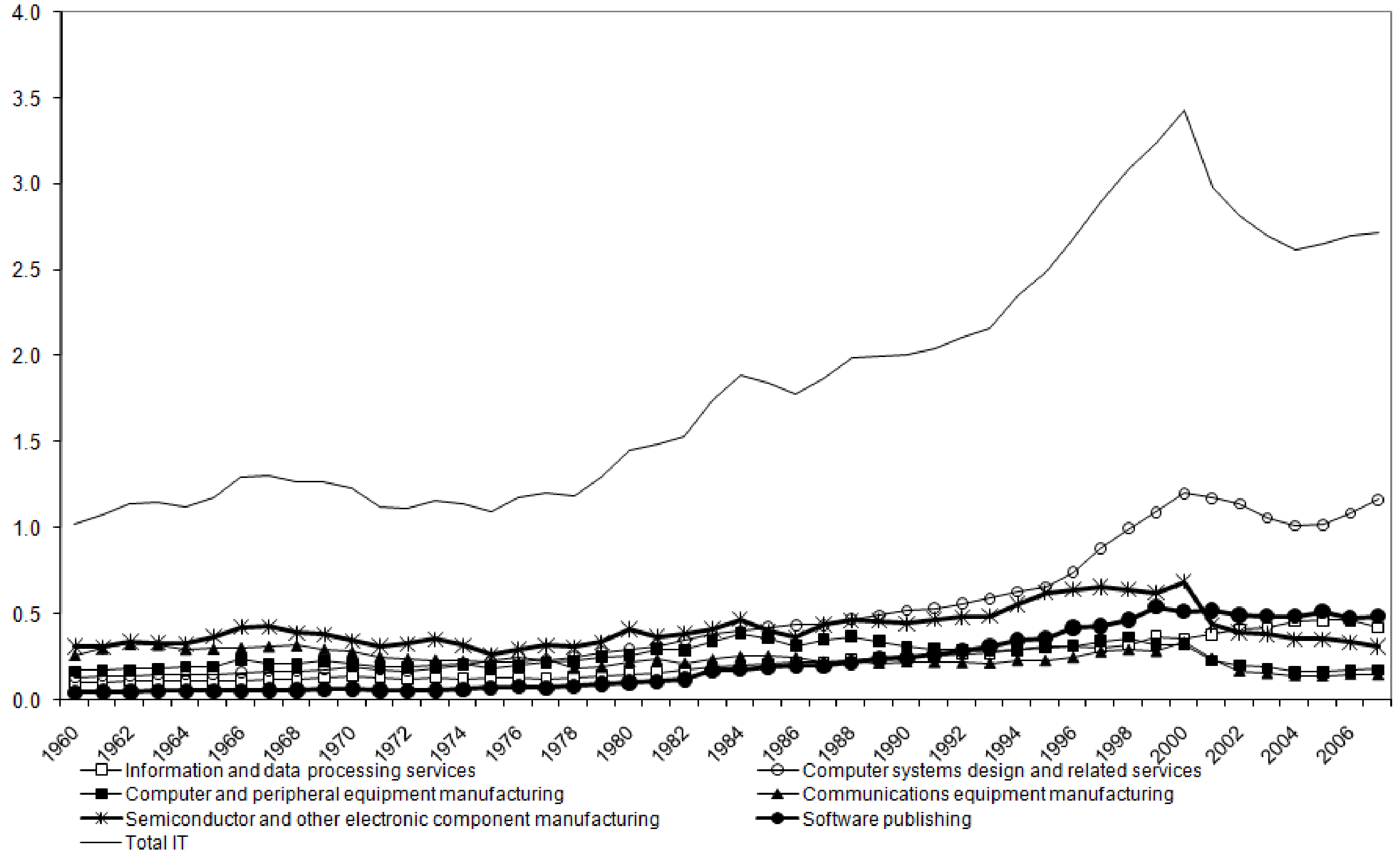
Notes: All figures are annual averages. Value-added weights are industry value-added as a share of aggregate value-added. Domar weights are industry output as a share of aggregate value-added. A contribution is a share-weighted growth rate.

# Figure 1: Relative Prices of IT Industry Output, 1960-2007



## Figure 2: Value Added Shares of Information Technology by Type, 1960-2007

Share of Current Dollar Value Added.



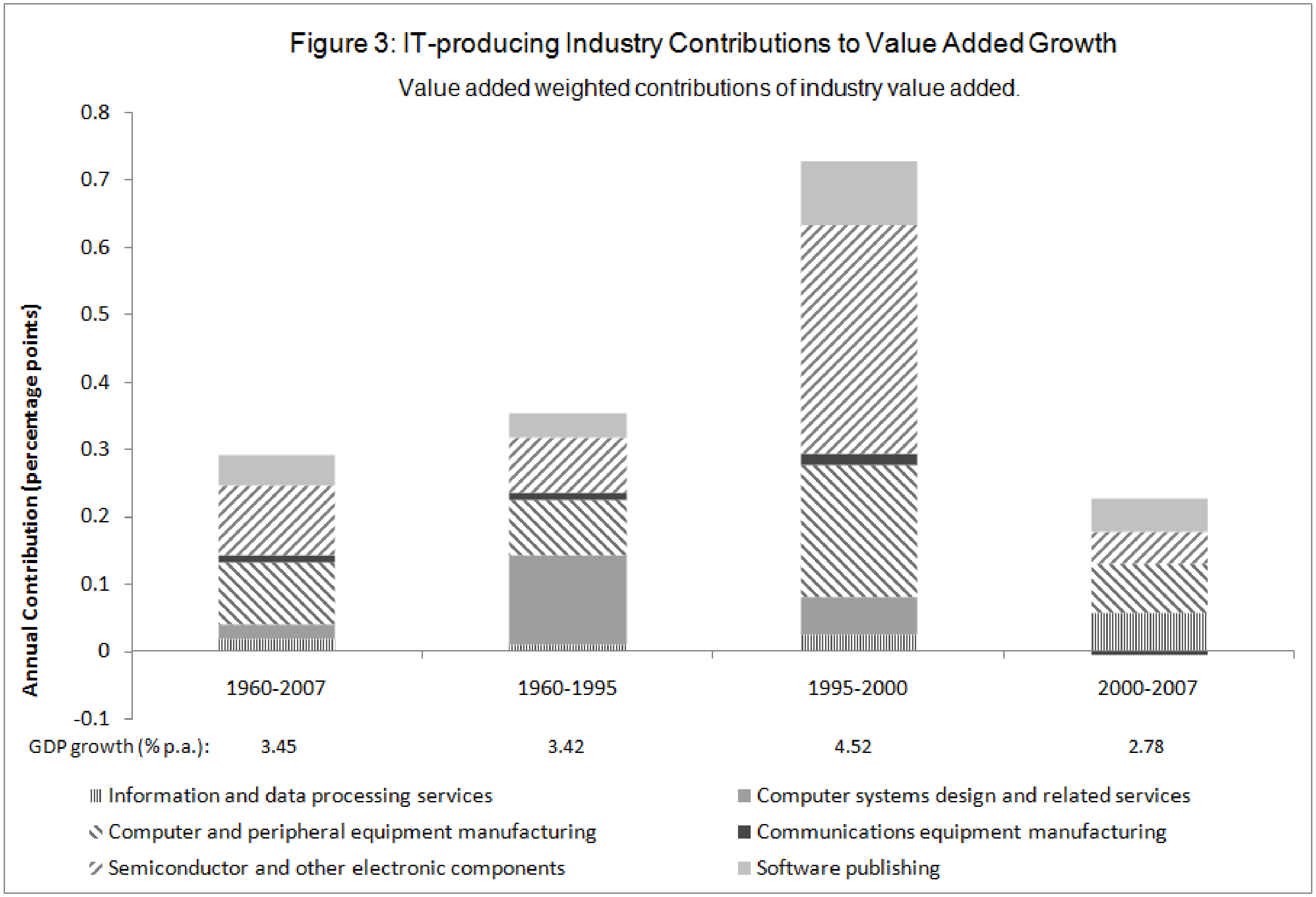


Figure 3: IT-producing Industry Contributions to Value Added Growth
Value added weighted contributions of industry value added.
Annual Contribution (percentage points)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
1960-2007
1960-1995
1995-2000
2000-2007
GDP growth (% p.a.):
3.45
3.42
4.52
2.78
Information and data processing services
Computer systems design and related services
Computer and peripheral equipment manufacturing
Communications equipment manufacturing
Semiconductor and other electronic components
Software publishing

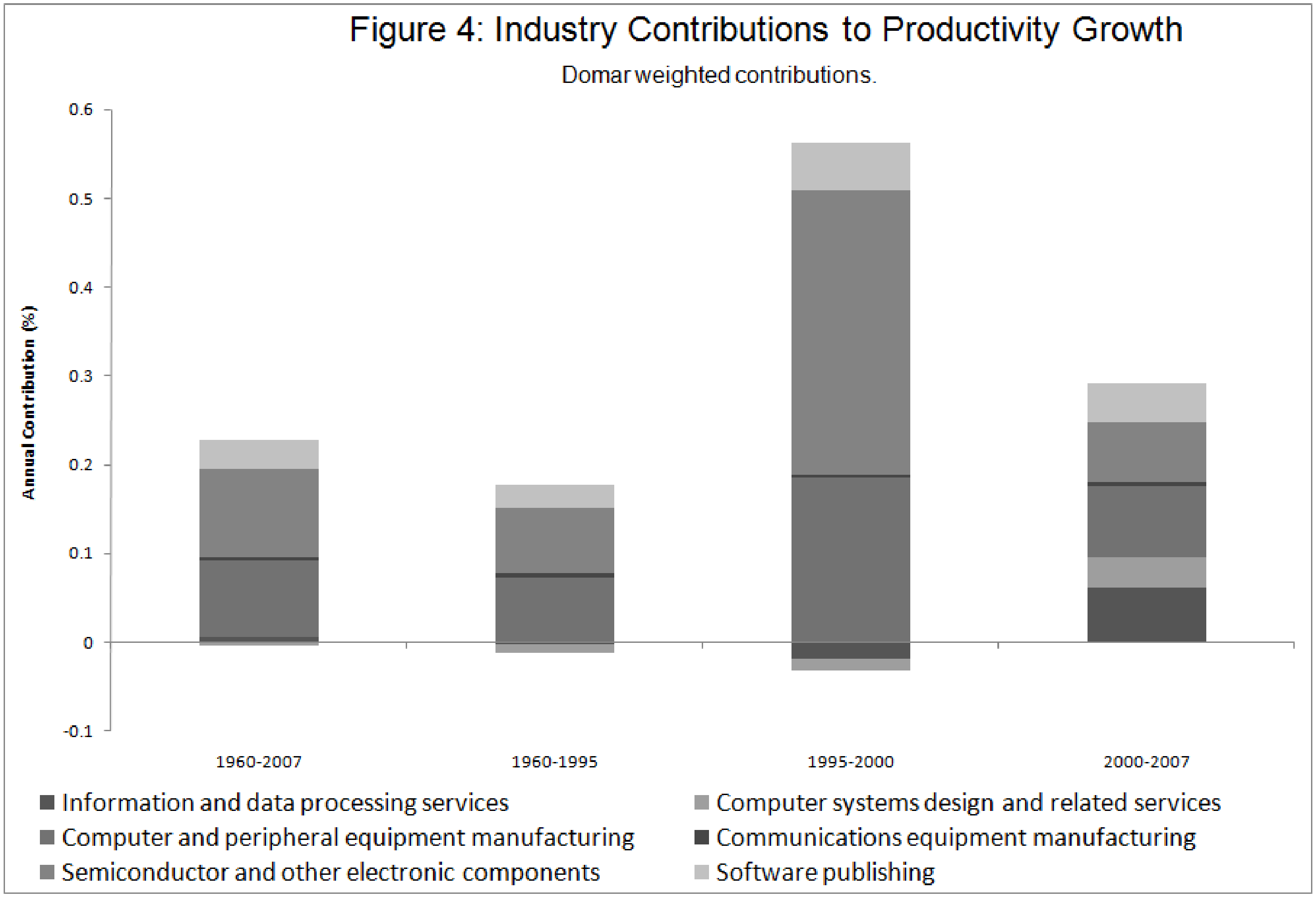


Figure 4: Industry Contributions to Productivity Growth
Domar weighted contributions.
Annual Contribution (%)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
1960-2007
1960-1995
1995-2000
2000-2007
Information and data processing services
Computer systems design and related services
Computer and peripheral equipment manufacturing
Communications equipment manufacturing
Semiconductor and other electronic components
Software publishing

**Figure 5: Industry Contributions to Value Added 1960-2007**

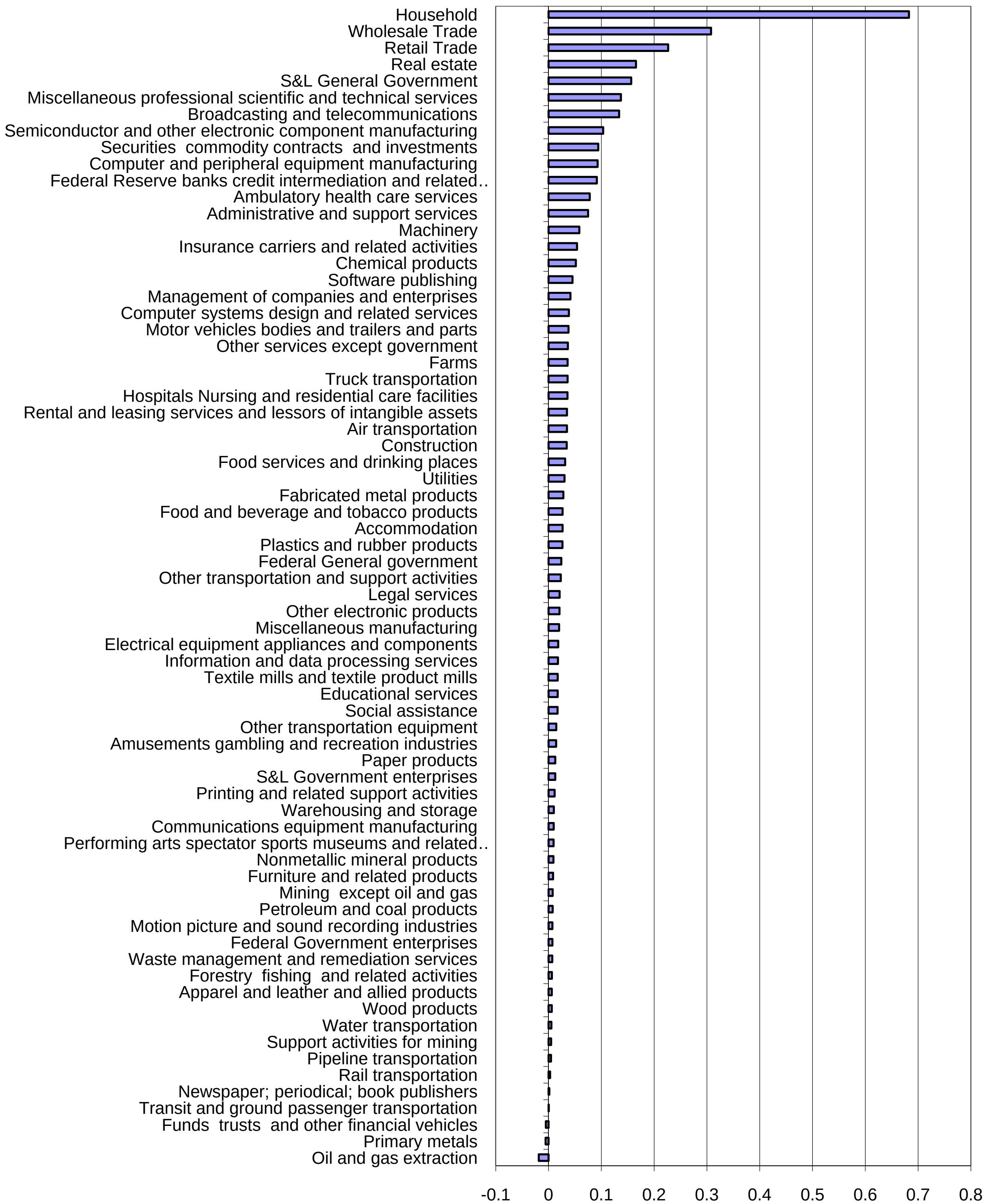


**Figure 6: ndustry Contributions to Productivity 1960-2007**