A PROTOTYPE INDUSTRY-LEVEL PRODUCTION ACCOUNT FOR THE UNITED STATES, 1947-2010

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Introduction

The computer equipment manufacturing industry comprised only 0.2 percent of U.S. value added from 1947-2010, but generated 2.3 percent of economic growth and 14.4 percent of productivity growth. By comparison agriculture accounted for 2.5 percent of U.S. value added, but only 1.8 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 eight times as fast. However, agriculture accounted for eighteen 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 fifteen 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. During the lengthy recovery from the Great Recession of 2007-2009 in the U.S., 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 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 65 industries for the period 1947-2010 and uses the North American Industry Classification System (NAICS). We have updated and extended the NAICS data set for 70 industries for the period 1960-2007 presented in Jorgenson, Ho, and Samuels (2012). The U.S. statistical system has shifted gradually to NAICS, beginning with the Business Census of 1997. The national accounts converted to NAICS in the 2003 Comprehensive Revision of the National Income and Product Accounts.

Our objective is to provide a long-term historical perspective on the sources of postwar U.S. economic growth at the industry level. An important feature of our new data set is that we incorporate data on output and intermediate input for the period 1998-2010 from the Industry Economic Accounts generated by the Bureau of Economic Analysis and described by Mayerhauser and Strassner (2010). This will ease the task of incorporating official industry data as they become available. We have extrapolated these industry data backward from the 65-sector industry classification used by BEA, using data from our earlier studies, as well as benchmark input-output tables beginning in 1947.

This paper begins with a brief summary of the methodology for productivity measurement. This methodology is consistent with the international standards 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).[1]

Industry-level production accounts are now prepared on a regular basis by national statistical agencies in Australia, Canada, Denmark, Finland, Italy, The Netherlands, and Sweden. Augmented by production accounts from the EU KLEMS project described by Timmer, Inklaar, O'Mahony, and van Ark (2010), these accounts can be used in international comparisons of patterns of structural change like those presented by Jorgenson and Timmer (2011). The World KLEMS Initiative will make it possible to extend these comparisons to forty countries around the world, including important developing and transition economies.

Regional organizations in Asia and Latin America have now joined the European Union in supporting research on KLEMS data sets. Due to the growing recognition of the importance of KLEMS data, an effort is underway to extend the KLEMS framework to emerging and transition economies. These include Argentina, Brazil, Chile, China, India, Indonesia, Mexico, Russia, Turkey, and Taiwan. Brazil, Russia, India, and China have been widely recognized as future leaders in the growth of the world economy.

[1] Current data for the participating countries are available at the EU KLEMS website: http://www.euklems.net/.

The Latin American Chapter of the World-KLEMS Initiative, LA-KLEMS, was established in December 2009 at a conference at ECLAC, the Economic Commission for Latin America and the Caribbean, in Santiago, Chile. This Chapter is coordinated by ECLAC and includes seven research organizations in four leading Latin American countries – Argentina, Brazil, Chile, and Mexico.[2] Mario Cimoli, Andre Hofman, and Nanno Mulder (2010) summarize the results of the initial phase of the LA-KLEMS project. The Asian Chapter of the World KLEMS Initiative, Asia-KLEMS, was founded in December 2010 and the first Asia KLEMS Conference was held at the Asian Development Bank Institute in Tokyo in July 2011. The Asia-KLEMS Committee includes representatives of major Asian countries, including China, India, Japan, South Korea, and Singapore.[3]

International comparisons of patterns of output, inputs, and productivity are very challenging, but have become crucial to growth strategy in an increasingly globalized world economy. Research on international supply chains has established the need for integration of KLEMS data sets with information on trade. The World Input-Output Database (WIOD) augments industry-level data sets for the forty countries of the World KLEMS Initiative with data on international trade among these countries. This project has produced a database that includes industry-level patterns of production and trade for all of the participating countries. The World

[2] Additional information about LA-KLEMS is available on the project website: http://www.cepal.org/cgi-bin/getprod.asp?xml=/la-klems/noticias/paginas/4/40294/P40294.xml&xsl=/la-klems/tpl-i/p18f-st.xsl&base=/la-klems/tpl-i/top-bottom.xsl An overview of LA-KLEMS is presented by Hofman (2012).
[3]Additional information about Asia KLEMS is available on the project website: http://asiaklems.net/1_1.html An overview of Asia KLEMS is presented by Pyo (2012). Updated data for Australia, Canada, Japan, Korea, and the U.S. – the original participants in the EU KLEMS study from outside the European Union –are posted on the World KLEMS website: http://www.worldklems.net/ As data become available from the Asia KLEMS and LA KLEMS projects, these data will also be posted on the World KLEMS website. More details are given by Timmer (2012).

Input-Output Database is a key resource for empirical research on international trade and the process of globalization.[4]

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 is summarized by Jorgenson (2009a) in *The Economics of Productivity*. The final section sums up the paper.

New Architecture

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 effect, the Statistical Commission reversed the position of the United Nations' *System of National Accounts 1993* (1993), which had stated that it was impossible

[4] Information about WIOD is available on the project website: http://www.wiod.org/participants/index.htm The relationship of WIOD and World KLEMS is discussed by Timmer (2012).

to decompose income from capital (called net operating surplus) into price and quantity components.[5]

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) 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[6]:

> 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.

[5] United Nations, *System of National Accounts 1993*, p. 403.
[6] 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. Data on capital and labor inputs are provided by BLS. The results are reported by Michael Harper, Brent Moulton, Steven Rosenthal, and David Wasshausen (2009) and will be updated annually.[7] 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.

Reflecting the international consensus on productivity measurement at the industry level, 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. This is described by Ann Lawson, Brian Moyer,

[7] The most recent data set is available at: http://www.bea.gov/national/integrated_prod.htm

Sumiye Okubo and Mark Planting (2006), and Moyer, Marshall Reinsdorf, and Yuskavage (2006). Moyer (2012) has described plans to integrate BEA's industry data with the NIPAs, beginning with the benchmark revision of 2013. The NIPAs and the 2007 benchmark input-output table will be prepared within the same framework. The annual input-output data will be revised periodically along with the NIPAs and will form a continuous time series.

BEA's annual input-output data are employed in the industry-level production accounts presented by Susan Fleck, Rosenthal, Matthew Russell, Erich Strassner, and Lisa Usher (2012) in their paper, "A Prototype BEA/BLS Industry-Level Production Account for the United States." This covers the period 1998-2010 for the 65 industrial sectors used in the NIPAs. The capital and labor input are provided by BLS, while the data on output and intermediate inputs are generated by BEA.

A Prototype Industry-Level Production Account for the United States, 1947-2010.

The incorporation of data on labor and capital inputs in constant prices into the national accounts is described in Chapters 19 and 20 of the *2008 System of National Account*, published in 2009. Jorgenson and Schreyer (2012) have shown how to integrate a complete system of production accounts at the industry level, like that provided by KLEMS data sets, into the *2008 System of National Accounts.* To illustrate the application of these data sets we present a prototype production account for the United States for 1947-2010.

In December 2011 the Bureau of Economic Analysis (BEA) released a new industry-level data set. This has a number of features that are useful in constructing KLEMS data sets. First, the data set employs the North American Industry Classification System (NAICS). The NIPAs have been based on NAICS since the benchmark revision of 2003. The new industry data set integrates three separate industry programs: benchmark input-output tables released every five years, annual input-output tables, and gross domestic product by industry, also released annually. The annual input-output tables and gross domestic product by industry form consistent time series. The input-output tables provide data on the output side of the national accounts along with intermediate inputs in current and constant prices.

Planting, formerly head of the input-output accounts at BEA, has developed a time series of input-output tables in current prices covering the period 1947-1997 on a NAICS basis. This incorporates all earlier benchmark input-output tables for the U.S., including the first benchmark table for 1947. BEA has linked these input-output tables to the official tables for 1998-2010. Jorgenson, Ho, and Samuels (2012) have constructed input-output tables in constant prices for 1947-2010 on a NAICS basis. This data set incorporates input-output tables in constant prices from Jorgenson, Gollop, and Fraumeni for 1948-1979, from Jorgenson, Ho, and Stiroh for 1977-2000, and from Jorgenson, Ho, and Samuels (2012a) for 1960-2007.[8] We incorporate data on capital and labor inputs in constant prices from the same sources to obtain an industry-level production account for the United States covering the period 1947-2010. This KLEMS data set is consistent with BEA's annual BEA input-output tables for 1998-2010.

We illustrate the application of the prototype industry-level production account by analyzing postwar U.S. economic history for three broad periods. These are the Postwar Recovery, 1947-1973, the Big Slump following the energy crisis of 1973, 1973-1995, and the period of Growth and Recession, 1995-2010. To provide more detail on the period of Growth and Recession, I will consider the sub-periods 1995-2000, 2000-2005, and 2005-2010 – the Investment Boom, the Jobless Recovery, and the Great Recession.

[8] Data for 1960-2007 are posted on the World KLEMS website: http://www.worldklems.net/data/index.htm

The NAICS industry classification includes the industries identified by Jorgenson, Ho, and Samuels (2012b) as IT-producing industries, namely, computers and electronic products and two IT-services industries, information and data processing and computer systems design. Jorgenson, Ho and Samuels (2012b) have classified industries as IT-using if at least fifteen percent of capital input in the industry was associated with IT equipment and software in 2005. This sector now comprises about 45 percent of the U.S. economy. The IT-producing industries include about three percent, while Non-IT industries make up the remainder. The IT-using industries are mainly in trade and services, while most manufacturing industries are in the Non-IT sector. The NAICS industry classification provides much more detail on services and trade, especially the industries that are intensive users of IT. I will begin by discussing the results for the IT-producing sectors, now defined to include the two IT-service sectors.

The contribution of each industry to value added is the growth rate of value added for the industry, weighted by its share in value added for the economy as a whole. Prices of computers and electronic products have declined rapidly, relative to the GDP deflator, since the commercialization of the electronic computer in 1959. This trend accelerated with the switch from vacuum tubes to semiconductors around 1970. The two IT-services sectors have had declining prices, relative to the GDP deflator, since around 2000. Figure 1 reveals a steady increase in the share of IT-producing industries in value added since 1947. This is paralleled by a decline in the contribution of the Non-IT industries, while the share of IT-using industries has remained relatively constant. Figure 2 decomposes the growth of value added for the period 1995-2010. The contributions of the IT-producing and IT-using industries peaked during the Investment Boom of 1995-2000 and have declined since then. However, the contribution of the Non-IT industries has also declined sharply and became negative during the Great Recession. Figure 3 gives the contributions to value added for the 65 individual industries over the period 1947-2010.

In order to assess the relative importance of productivity growth at the industry level as a source of U.S. economic growth, 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 rapidly than the Domar-weighted averages of industry capital and labor input growth rates, so that the reallocations are positive. When industries with lower prices for inputs grow more rapidly, the reallocations are negative.

Figure 4 shows that the contributions of IT-producing, IT-using, and Non-IT industries to aggregate productivity growth are similar in magnitude for the period 1947-2010. The Non-IT industries greatly predominated in the growth of value added during the Postwar Recovery, 1947-1973, but this contribution became negative after 1973. The contribution of IT-producing industries was relatively small during this period, but became the predominant source of growth during the Big Slump, 1973-1995, and increased considerably during the Resurgence and Recession of 1995-2010. The IT-using industries contributed substantially to U.S. economic growth during the postwar recovery, but disappeared during the Big Slump, 1973-1995, before reviving after 1995. The reallocation of capital input made a small but positive contribution to growth of the U.S. economy for the period 1947-2010, while the contribution of reallocation of labor input was negligible. Both reallocations were positive during the Postwar Recovery and both were negative during the Resurgence and Recession, but very small in magnitude.

Considering the period 1995-2010 in more detail in Figure 5, the IT-producing industries predominated as a source of productivity growth during the period as a whole. The contribution of these industries remained substantial during each of sub-periods – 1995-2000, 2000-2005, and 2005-2010 – despite the strong contraction of economic activity during the Great Recession of 2007-2009. The contribution of the IT-using industries was slightly greater than that of the IT-producing industries during the first two sub-periods, but become negative and small in magnitude during the period of the Great Recession. The Non-IT industries contributed positively to productivity growth during the Investment Boom of 1995-2000, but were almost negligible during the Jobless Recovery and became substantially negative during the Great Recession. The contributions of reallocations of capital and labor inputs were very small and negative during the period as a whole and fluctuated from negative in 1995-2000 to positive in 2000-2005. Figure 6 gives the contributions of each of the 65 industries to productivity growth for the period as a whole.

The computer and electronic products industry was the leading contributor to U.S. economic growth during this period.

Research on the impact of investment in IT equipment and software on economic growth is summarized by Jorgenson (2009) in *The Economics of Productivity*. 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 input. 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 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 the *cost of capital*, introduced by Jorgenson (1963). 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 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. 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.

Productivity growth was identified as the predominant source of economic growth by Solow (1957). However, Figure 7 shows that the productivity growth was far less important than the contributions of capital and labor inputs. For the period 1947-2010 productivity accounts for about twenty percent of U.S. economic growth. The contribution of capital input accounts for the largest share of growth for the period as a whole, while the contribution of labor input accounts for the rest. The great bulk of U.S. economic growth is due to replication of established technologies rather than 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 modest portion of economic growth, this portion is vital for maintaining gains in the U.S. standard of living in the long run.

The contribution of capital input exceeded that of innovation, while the contribution of labor input was similar to that of innovation during the Postwar Recovery, 1947-1973. The standard explanation for the substantial importance of innovation during the period is the backlog of new technologies available at the end of the World War II. During the Big Slump of 1973-1995, growth of inputs remained about the same. The “slump” was due to the sharp slowdown in productivity growth. The contribution of labor input increased in importance, relative to the contribution of capital input. The contributions of college-educated workers and investment in information technology grew substantially, while the contributions of non-college workers and non-information technology declined considerably. After 1995 the rate of U.S. growth continued to decline and the contribution of non-college workers almost disappeared. Productivity growth revived and investment in information technology became the predominant source of the contribution of capital input.

Figure 8 shows that all of the sources of economic growth we have identified contributed to the U.S. growth acceleration after 1995, relative to the Big Slump. 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 1947-2010. The contribution of investment also declined below the long-term average, but the shift from Non-IT to IT capital input remained. The contribution of labor input dropped precipitously, accounting for most of the decline in economic growth during the Jobless Recovery. 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 Jobless Recovery was the continued growth in productivity, indicating a continuing surge of innovation. Both IT and Non-IT investment continued to contribute to U.S. economic growth during the recession period after 2005, while productivity growth became negative, reflecting a widening gap between actual and potential growth of output. The contribution of college-educated workers remained positive and substantial, while the contribution of non-college workers became strongly negative.

Conclusion

The new framework for productivity measurement employed in constructing KLEMS data sets reveals that replication of established technologies through growth of capital and labor inputs, recently through the growth of college-educated workers and investments in both IT and Non-IT capital, 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.[9] Studies are now underway to extend these comparisons to individual industries for the forty countries included in the World KLEMS Initiative.

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Figure1: Contributions of Industry Groups to Value Added Growth, 1947-2010

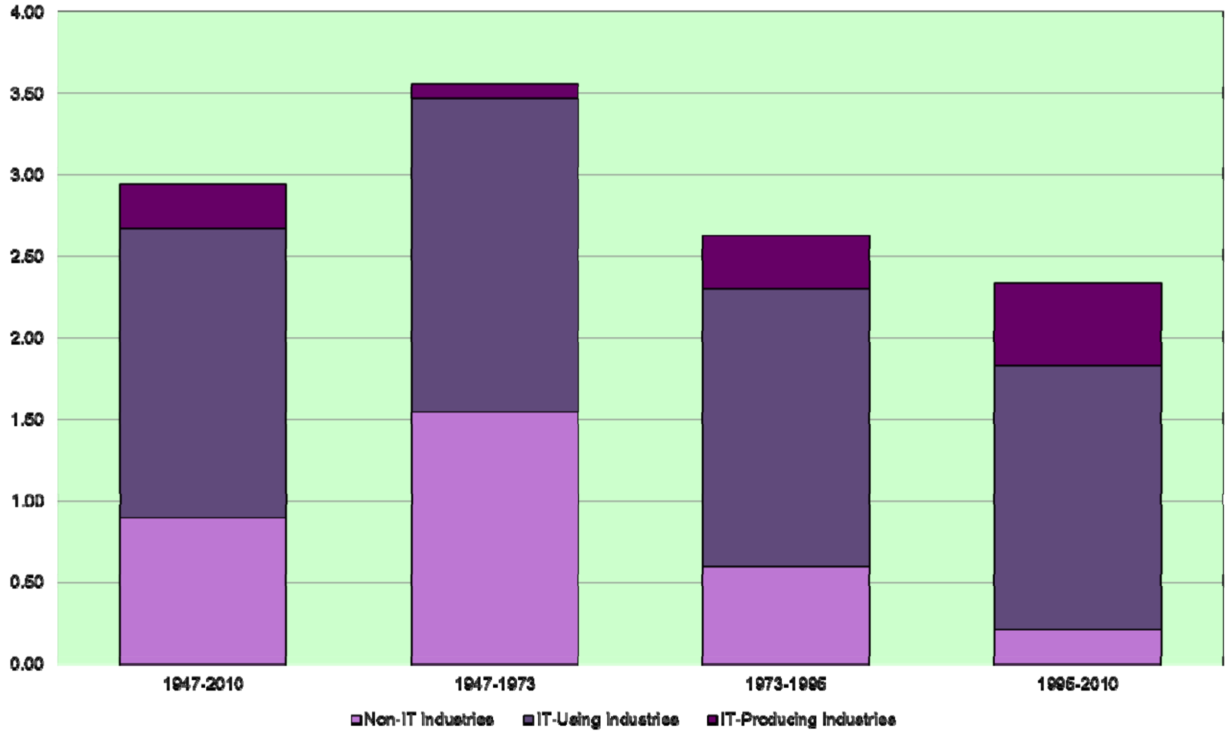


Figure 2: Contributions of Industry Groups to Value Added Growth, 1995-2010

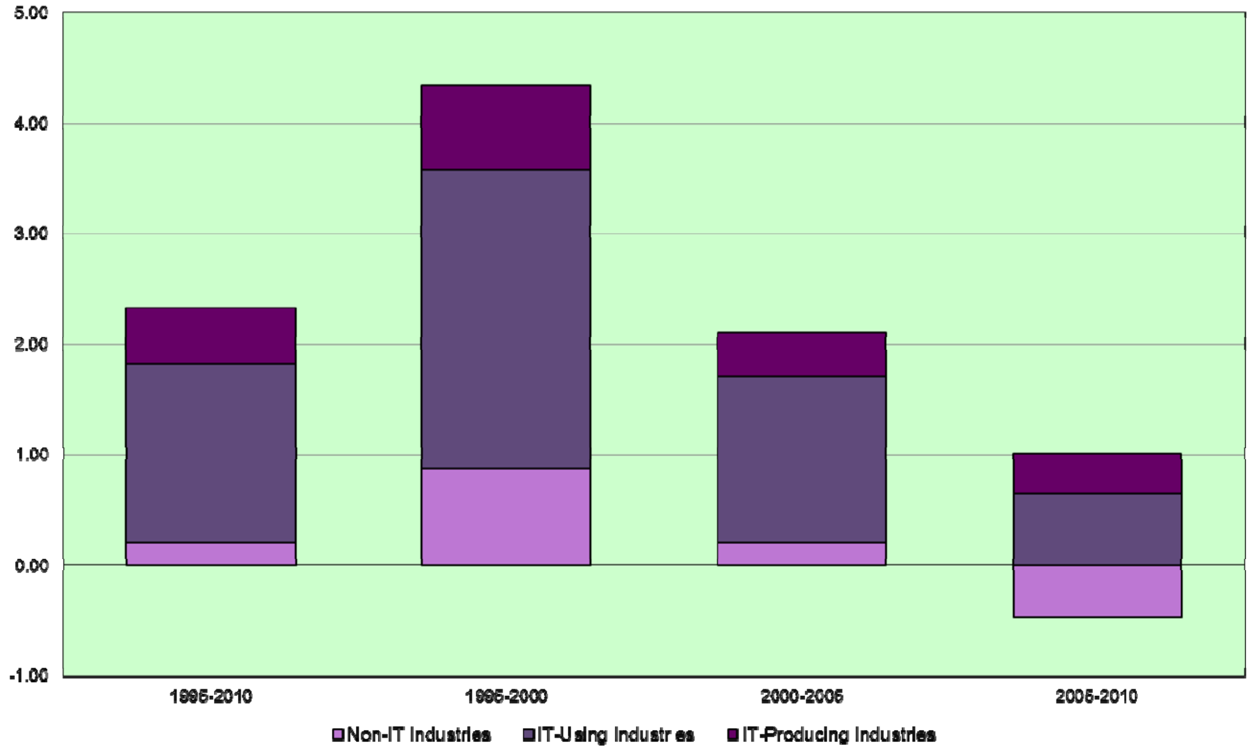


Figure 3: Contributions of Individual Industries to Value Added Growth

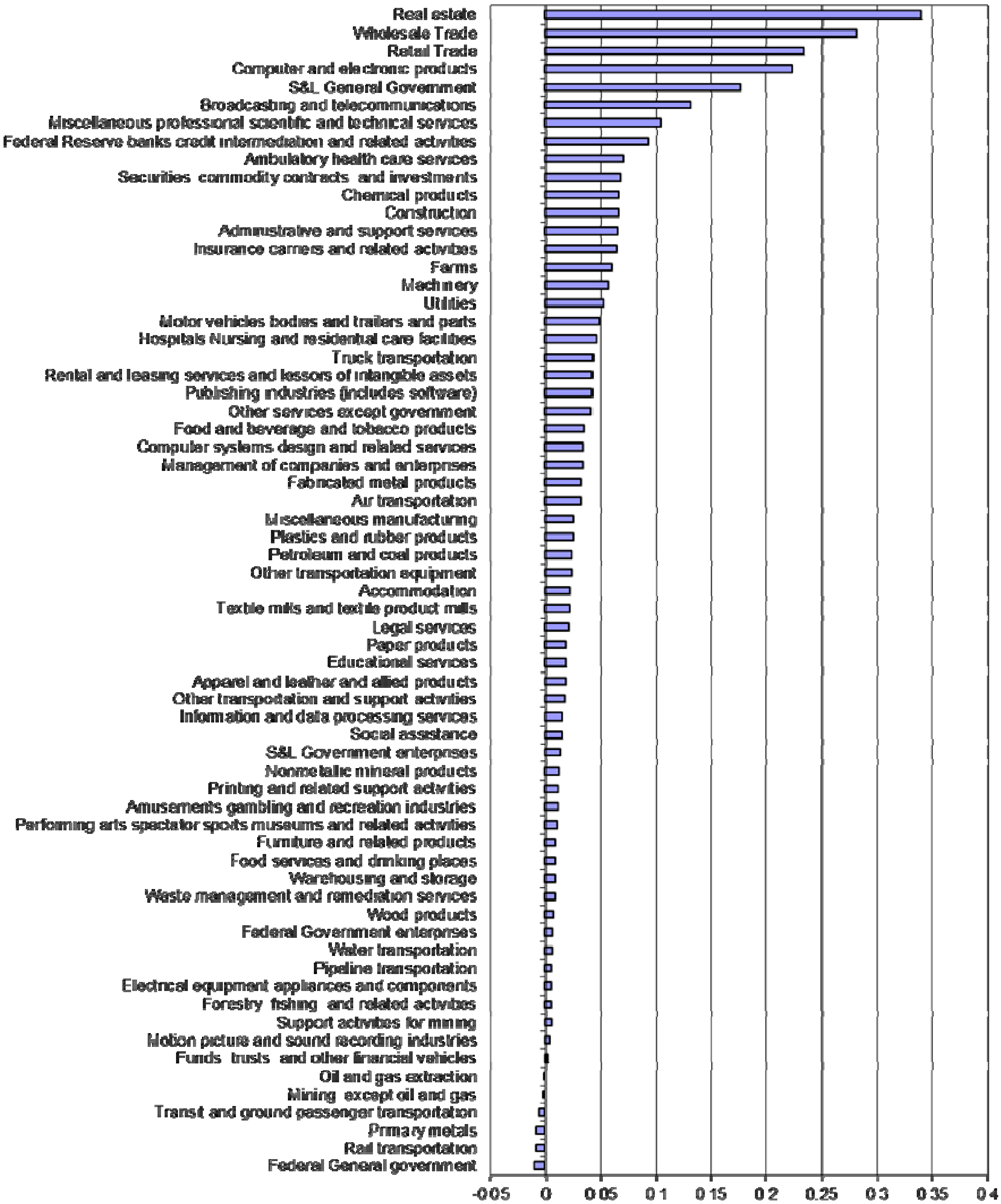


Figure 4: Contribution of Industry Groups to Productivity Growth, 1947-2010

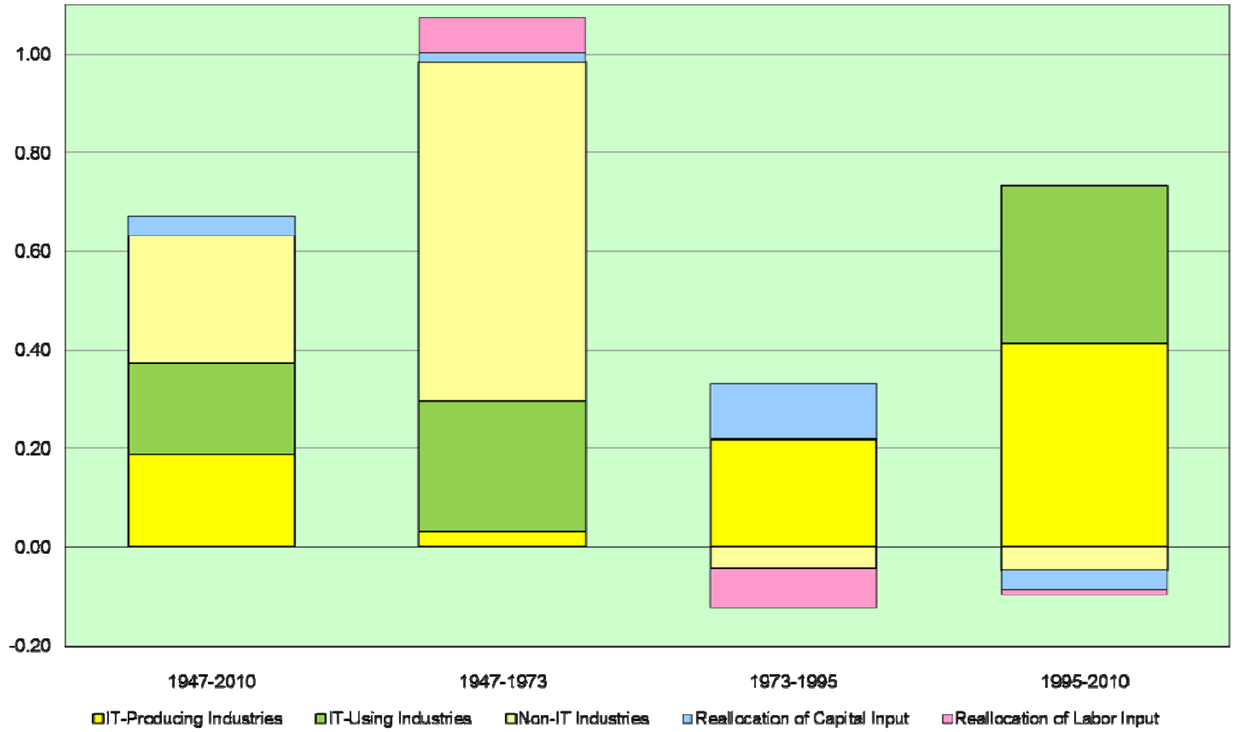


Figure 5: Contribution of Industry Groups to Productivity Growth, 1995-2010

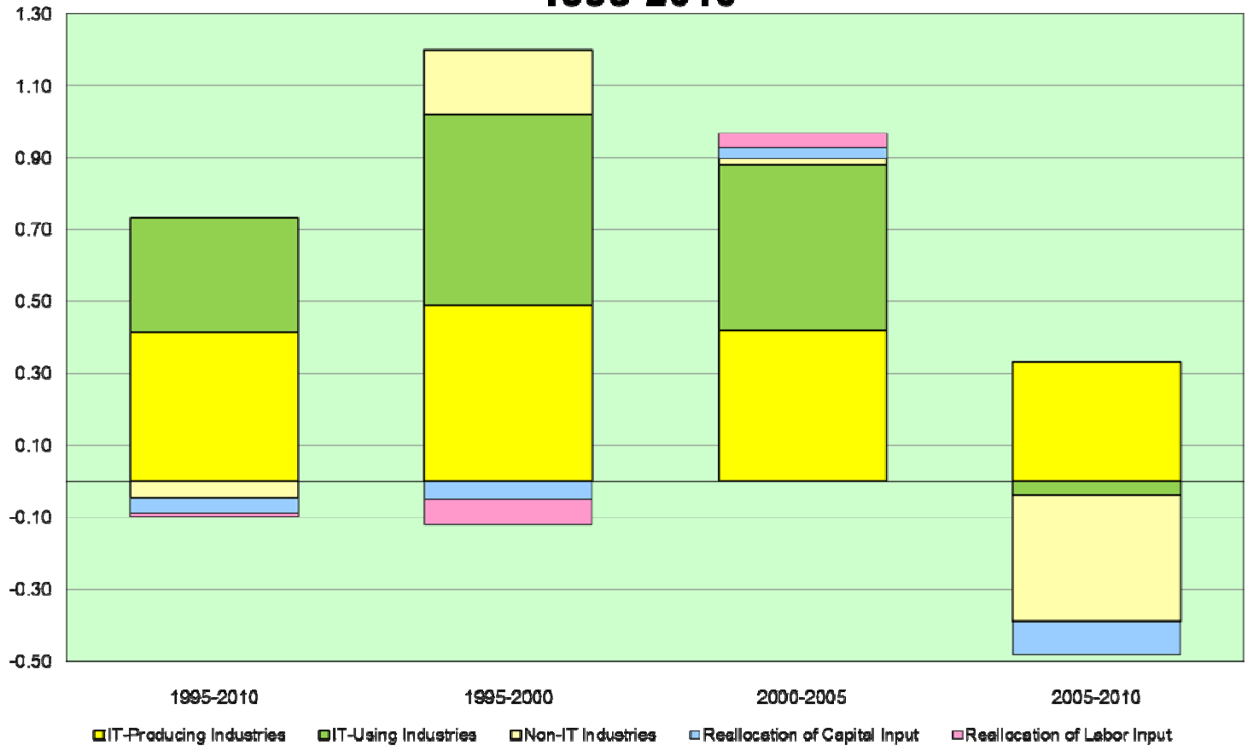
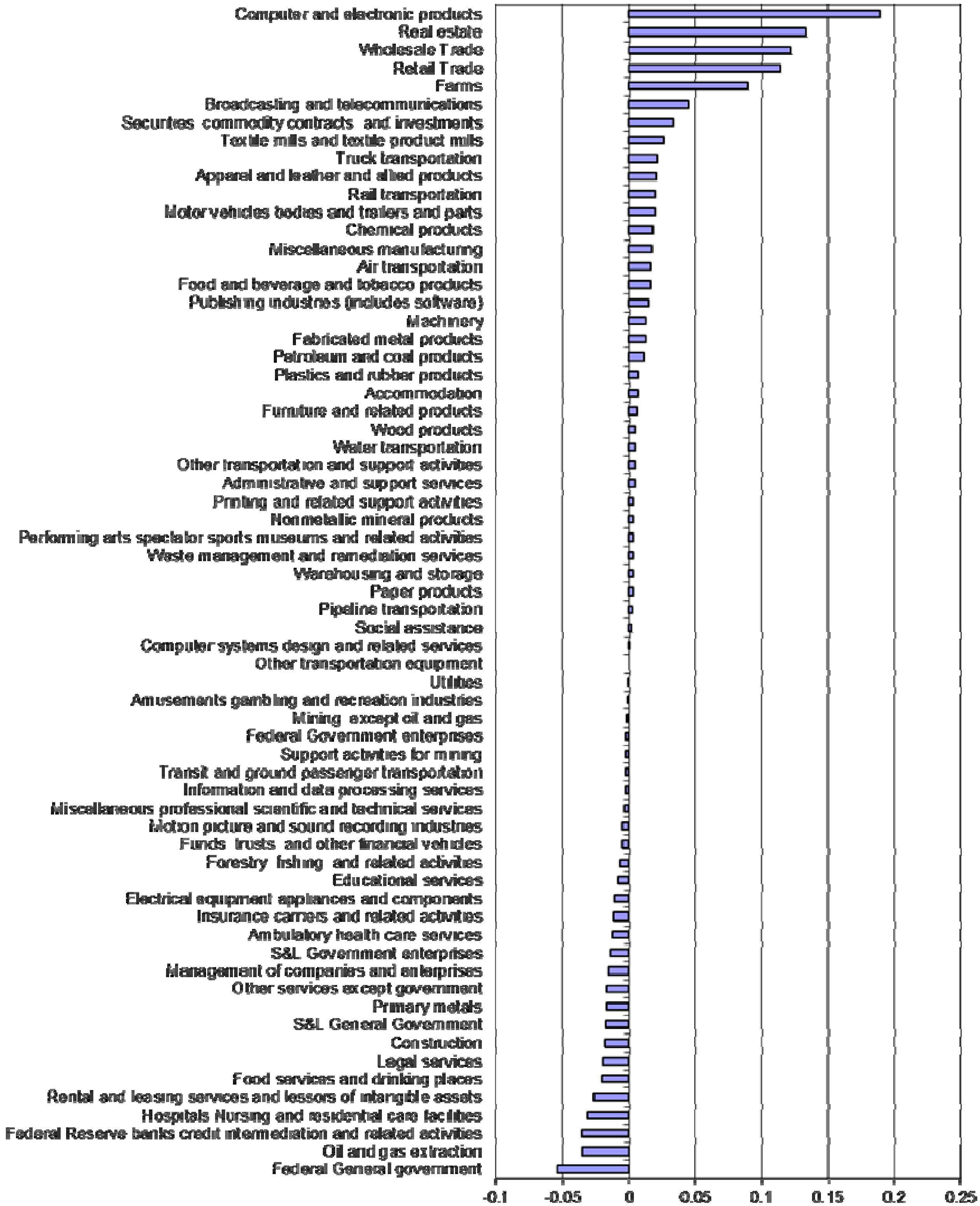


Figure 6: Contributions of Individual Industries to Productivity Growth



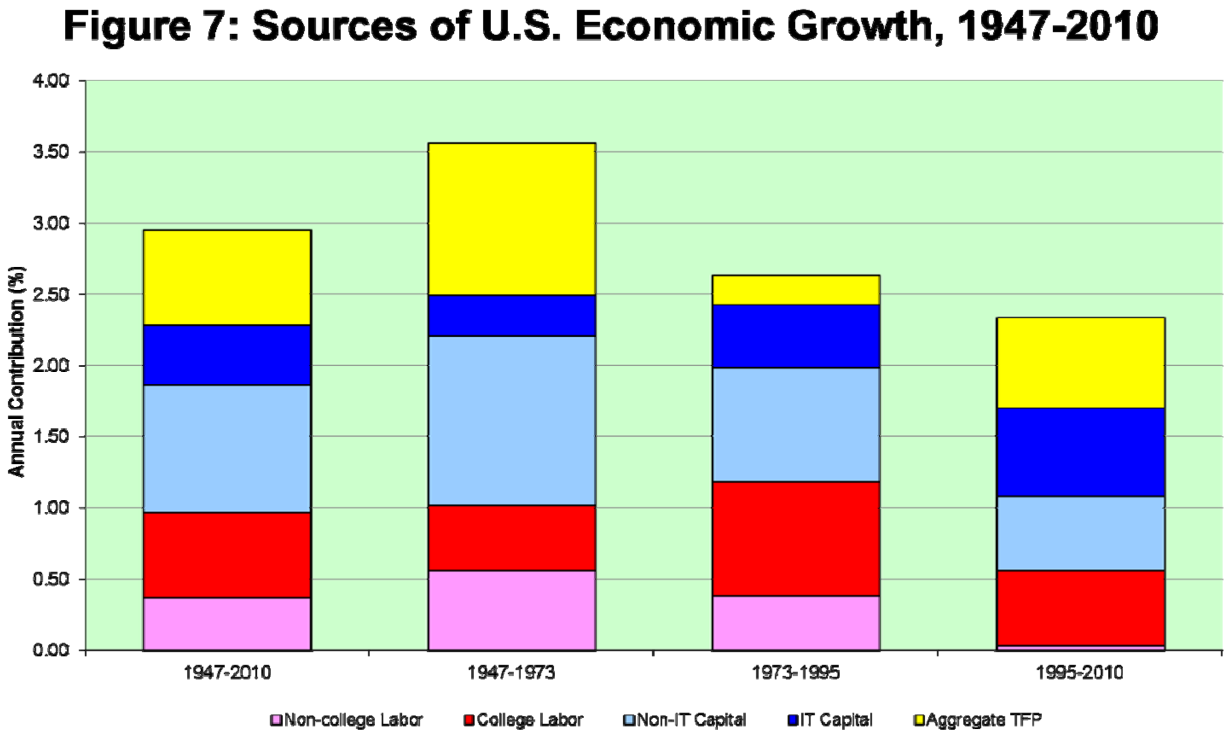


Figure 7: Sources of U.S. Economic Growth, 1947-2010
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Annual Contribution (%)
1947-2010
1947-1973
1973-1995
1995-2010
Non-college Labor
College Labor
Non-IT Capital
IT Capital
Aggregate TFP

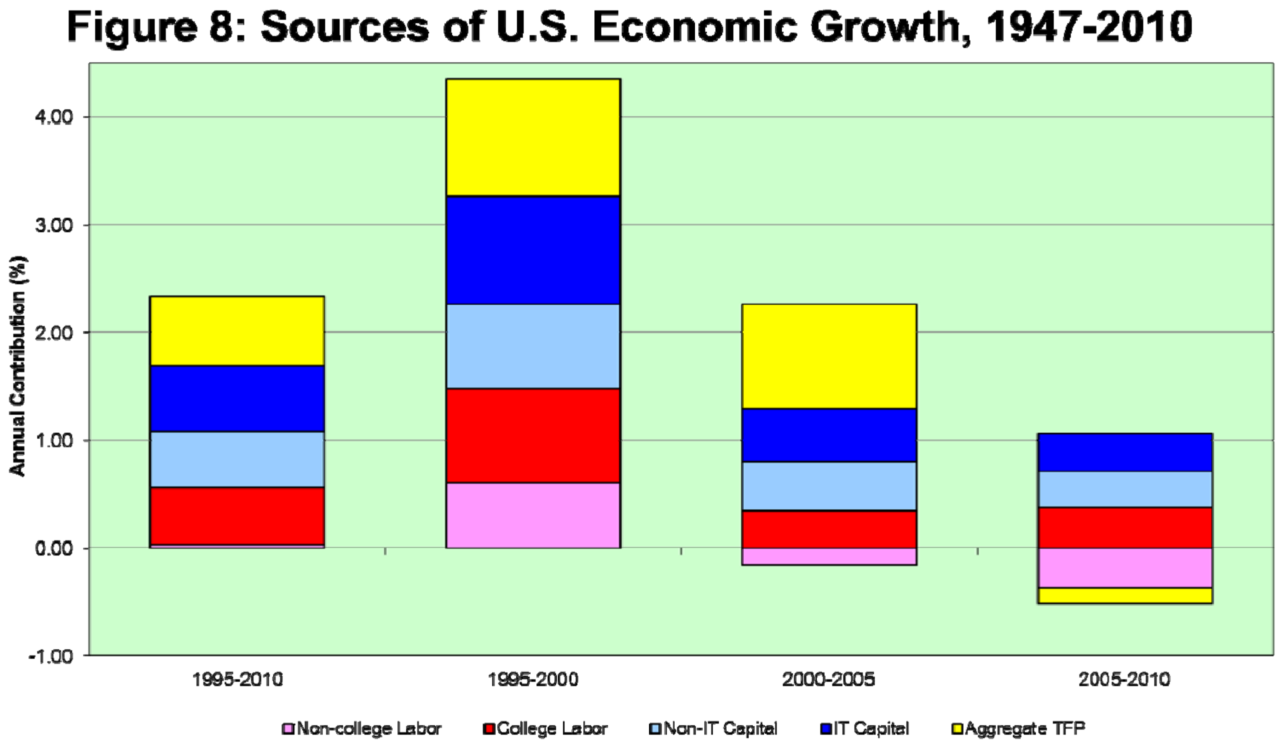


Figure 8: Sources of U.S. Economic Growth, 1947-2010
Annual Contribution (%)
4.00
3.00
2.00
1.00
0.00
-1.00
1995-2010
1995-2000
2000-2005
2005-2010
Non-college Labor
College Labor
Non-IT Capital
IT Capital
Aggregate TFP