EDUCATION, PARTICIPATION, AND THE

REVIVAL OF U.S. ECONOMIC GROWTH

by

Dale W. Jorgenson, Harvard University,

Mun S. Ho, Resources for the Future,

and

Jon D. Samuels, Bureau of Economic Analysis

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Introduction

Labor quality growth represents the upgrading of the labor force through higher educational attainment and greater experience. While much attention has been devoted to the aging of the labor force and the ongoing retirement of the baby boomers, the looming plateau in average educational attainment of U.S. workers has been overlooked. The educational attainment of people emerging from the educational system, while high, has been nearly constant for the past several decades. Rising average educational attainment is about to become part of U.S. economic history.

We define the participation rate for each age-sex group as the number of employed as a proportion of the population of that age group. This rate could also be called the *employment* participation rate. We consider participation rates for males and females of each age group by educational attainment. Participation rates increase with educational attainment for each age-sex category. The investment boom of 1995-2000 drew many younger and less educated workers into employment. After attaining a peak in 2000, the participation rates for these workers declined and then fell further during the Great Recession of 2007-2009.

Are the lower participation rates of the less-educated workers a "new normal" that will persist for some time? Or, will the continuing economic recovery enable these workers to resume

[1]The views expressed in this paper are solely those of the authors and not necessarily those of the U.S. Bureau of Economic Analysis or the U.S. Department of Commerce.

the higher rates of participation that preceded the Great Recession? The answers to these questions provide the keys to the future growth of the U. S. economy. We consider alternative projections of age-specific participation rates for each educational group in order to illuminate the potential sources of a revival in U.S. economic growth.

To analyze the long-term growth of the U.S. economy we have constructed a new data set on the growth of U.S. output and productivity by industry for 1947-2012. This includes the output for each of the 65 industries represented in the U.S. national accounts, as well as the inputs of capital (K), labor (L), energy (E), materials (M), and services (S). The key indicator of innovation is productivity growth for each industry, where productivity is the ratio of output to input.

We build on the work of Jorgenson, Ho, and Kevin J. Stiroh (2005), who presented a less detailed industry-level data set for the U.S. economy for 1977-2000. Data for 1947-1977 capture the development of the telecommunications services and equipment industries before the commercialization of semiconductor technology. Data for 2000-2012 highlight the slowdown in productivity growth and the drop in investment during and after the Great Recession of 2007-2009.

We project the future growth of the U.S. economy by adapting the methodology of Jorgenson, Ho, and Stiroh (2008).[2] We aggregate over industries to obtain data on the sources of U.S. economic growth and project the future growth of hours worked and labor productivity. We discuss the methodology in more detail in an Appendix and compare the results with the projections summarized by David Byrne, Steven Oliner and Daniel Sichel (2013).

Paul Schreyer's OECD (2001) manual, *Measuring Productivity*, established international standards for economy-wide and industry-level productivity measurement, exemplified by Jorgenson, Frank M. Gollop, and Barbara M. Fraumeni (1987). The methodology for our new data

[2] Jorgenson and Khuong M. Vu (2013) employ this methodology to project the growth of the U.S. and the world economy.

set is consistent with the OECD standards. Our data set comprises a prototype production account within the framework of the U.S. national accounts. We aggregate industries by means of the production possibility frontier employed by Jorgenson, Ho, and Stiroh (2005) and Jorgenson and Schreyer (2013). This links industry-level data with the economy-wide data reported by Michael Harper, Brent R. Moulton, Steven Rosenthal, and David B. Wasshausen (2009).[3]

In the following section of the paper we analyze the changing sources of postwar U.S. economic growth. We divide the postwar period into three broad sub-periods: the Postwar Recovery, 1947-1973, the Long Slump following the 1973 energy crisis, 1973-1995, and the recent period of Growth and Recession, 1995-2012. We focus more narrowly on the period of Growth and Recession by considering the sub-periods 1995-2000, 2000-2007, and 2007-2012 – the Investment Boom, the Jobless Recovery, and the Great Recession.

We show that the great preponderance of U.S. economic growth since 1947 involves the replication of existing technologies through investment in equipment and software and expansion of the labor force. Contrary to the well-known views of Robert M. Solow (1957) and Simon Kuznets (1971), innovation accounts for a relatively modest twenty percent of U.S. economic growth. This is the most important empirical finding from the extensive recent research on productivity summarized by Jorgenson (2009).

The predominant role of replication of existing technologies in U.S. economic growth is crucial to the formulation of economic policy. During the protracted recovery from the Great Recession of 2007-2009, U.S. economic policy should focus on reviving investment and re-

[3] The most recent data set is available at: http://www.bea.gov/national/integrated_prod.htm. Our data for individual industries could also be linked to firm-level data employed in the micro-economic research reviewed by Chad Syverson (2011).

establishing the pre-recession participation rates of the labor force. Policies for enhancing the rate of innovation would have a very limited impact.

We consider the future growth of the U.S. economy for the period 2012-2022. We project future growth of the U.S. labor force from demographic projections. We project the future growth of the quality of labor input from the educational attainment of age cohorts that have recently entered the labor force. Without the revival of participation rates for the less-educated, we find that U.S. economic growth will slow substantially from the period 1990-2012, mainly due to a marked slowdown in labor quality growth.

We find that U.S. economic growth will recover from the Great Recession of 2007-2009 through the resumption of productivity growth and the recovery of investment in capital input. However, the growth rate of the U.S. economy in the next decade will depend critically on the performance of the relatively small number of sectors where innovation takes place, as well as the revival of the labor force participation rates that prevailed before the Great Recession. The final section of the paper presents our conclusions.

A Prototype Industry-Level Production Account for the United States, 1947-2012.

In December 2011 the Bureau of Economic Analysis (BEA) released a new industry-level data set. This integrated 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 input-output tables provide data on the output side of the national accounts along with intermediate inputs in current and constant prices. BEA's industry-level data set is described in more detail by Nicole M. Mayerhauser and Erich H. Strassner (2010).

Stefanie H. McCulla, Alyssa E. Holdren, and Shelly Smith (2013) summarize the 2013 benchmark revision of the NIPAs. A particularly significant innovation is the addition of intellectual property products such as research and development and entertainment, artistic, and literary originals. Investment in intellectual property is treated symmetrically with other types of capital expenditures. Intellectual property products are included in the national product and the capital services generated by these products are included in the national income. Donald D. Kim, Strassner and Wasshausen (2014) discuss the 2014 benchmark revision of the industry accounts, including the incorporation of intellectual property.

BEA's annual input-output data are employed in the industry-level production accounts presented by Steven Rosenthal, Matthew Russell, Samuels, Strassner, and Lisa Usher (2015) in their paper, "Integrated Industry-Level Production Account for the United States: Intellectual Property Products and the 2007 NAICS." This covers the period 1998-2012 for the 65 industrial sectors used in the NIPAs. The capital and labor inputs are provided by BLS, while output and intermediate inputs are generated by BEA.[4] Labor quality estimates are based on a version of our labor data set.

Our estimates of output and intermediate input for 1998-2012 are consistent with the BEA/BLS industry-level production accounts. For the period 1947-1997 we employ a time series of input-output tables in current prices on a NAICS basis constructed by Mark Planting, former head of the input-output accounts at BEA. This incorporates all earlier benchmark input-output tables for the US, including the first benchmark table for 1947. BEA has linked these input-output tables to the official tables for 1998-2012 that incorporate the 2014 benchmark revision of the industry accounts.

[4] Earlier data are presented by Susan Fleck, Rosenthal, Russell, Strassner, and Usher (2014). For current data, see: http://www.bea.gov/industry/index.htm#integrated.

We have constructed input-output tables in constant prices for 1947-2012, based on Jorgenson, Gollop, and Fraumeni (1987) for 1948-1979, Jorgenson, Ho, and Stiroh (2005) for 1977-2000, and Jorgenson, Ho, and Samuels (2012) for 1960-2007. We have revised, extended, and updated the data on capital and labor inputs in constant prices from the same sources. Finally, we obtain an industry-level production account for the United States, covering the period 1947-2012 in current and constant prices. This KLEMS-type data set is consistent with BEA's annual input-output tables for 1998-2012.

Changing Structure of Capital Input

Swiftly falling IT prices have provided powerful economic incentives for the rapid diffusion of IT through investment in hardware and software. A substantial acceleration in the IT price decline occurred in 1995, triggered by a much sharper acceleration in the price decline for semiconductors. The IT price decline after 1995 signaled even faster innovation in the main IT-producing industries – semiconductors, computers, communications equipment, and software – and ignited a boom in IT investment. Figure 1 presents price indices for 1973-2012 for asset categories included in our measures of capital input – equipment, computers, software, research and development, artistic originals, and residential structures.

The price of an asset is transformed into the price of the corresponding capital input by multiplying the assets price by the *cost of capital* introduced by Jorgenson (1963). The cost of capital includes the nominal rate of return, the asset-specific 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 high, relative to the cost of capital for the price of Non-IT capital input.

Schreyer's (2009) OECD Manual, *Measuring Capital*, provides detailed recommendations for the construction of prices and quantities of capital services. Incorporation of data on labor and capital inputs in constant prices into the national accounts is described in Chapters 19 and 20 of the United Nations *2008 System of National Accounts* (2009). 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."

To capture the impact of the rapid decline in IT equipment prices and the high depreciation rates for IT equipment we distinguish between the flow of capital services and the stock of capital. Figure 2 gives the share of IT in the value of total capital stock and the share of IT capital services in total capital input. The IT stock share rose from 1.4% in 1960 to 5.3% in 1995 on the eve of the IT boom and reached a high of 6.4% in 2001after the dot-com bubble. This share fell to 5.1% during the Jobless Recovery when there was a plunge in IT investment and only a partial recovery.

The share of the IT service flow in total capital input is much higher than the IT share in total capital stock. The share of the IT service flow in total capital input was 5-7% during 1960-84. The share of the IT service flow rose with the rapid growth in IT investment during 1995-2000, reaching a peak of 15.8% in 2000. The IT service flow then declined with the fall in the IT stock, ending with a sharp plunge in the Great Recession.

By contrast with the production of IT equipment, the IT services industries, information and data processing and computer system design, have shown more persistent growth. The share of the gross output of these two industries in the value of total gross output, shown in Figure 2, declined slightly from 1.45% in 2000 to1.29% in 2005 and then continued to rise, hitting a high of 1.60% in

2012. This reflects the displacement of in-house hardware and software by the growth of IT services like cloud computing.

Investment in intellectual property products (IPP) since 1973 is shown in Figure 3. This proportion grew during the Investment Boom of 1995-2000 to four percent of the U.S. GDP and has declined only slightly since the peak around 2000. Investment in research and development also peaked around 2000, but has remained close to this level through the Great Recession of 2007-2012.

The intensity of the use of IT capital input differs substantially by industry. Figure 4 shows the share of IT in total capital input for each of the 65 industries on the eve of the Great Recession in 2005. There is an enormous range from less than half percent in farms and real estate to about 90% for computer system design and information and data processing. The sectors with the higher-valued added growth have mostly high IT shares – the two IT service industries just noted, as well as publishing (72%), broadcasting and telecommunications (61%), securities (76%), and administrative services (59%). The high growth industries with low IT shares are petroleum products (3.9%), truck transportation (12%), rental and leasing (12%), social assistance (17%).

Stiroh (2002) found a positive relation between US industry-level TFP growth and IT intensity for 1977-2000. In Figure 5 we give a scatter plot of TFP growth during 1995-2010 and the 2005 share of IT capital services in total capital. The industries with the high IT intensity and high productivity growth are computer products, securities and commodities, computer system design, publishing, broadcasting and telecommunications, and administrative services. Industries with moderate IT intensity and high TFP growth include wholesale trade, water transportation, air transportation, miscellaneous manufacturing. The sectors with moderate IT intensity and negative TFP growth are educational services and legal services.

Changing Structure of Labor Input

Our measure of labor input recognizes differences in labor compensation for workers of different ages, educational attainment, and gender, as described in by Jorgenson, Ho and Stiroh (2005, Chapter 6). Labor quality growth is the difference between the growth of labor input and the growth of hours worked. For example, shifts in the composition of labor input toward more highly educated workers, who receive higher wages, contribute to the growth of labor quality. Of the 1.45% annual growth rate of labor input over 1947-2012, hours worked contributed 1.01 points and labor quality 0.43 points. Figure 6 shows the decomposition of changes in labor quality into age, education, and gender components.

During the Postwar Boom of 1947-1973 the massive entry of young, lower-wage workers contributed -0.04 percent annually to labor quality change, while increasing female workforce participation contributed -0.10 percent, reflecting the lower average wages of female workers. The improvement in labor quality is due to rising educational attainment, which contributed 0.37 percent. During the Long Slump of 1973-1995, the rise of female workers accelerated and the gender composition change contributed -0.15 points, while the aging of the work force contributed 0.17 points and education 0.40.

The contribution of higher educational attainment to labor quality growth accelerated to 0.48 percent during the period of Growth and Recession, 1995-2012. As workers gained in experience, aging of the work force also rose to 0.20, but this was more than offset by the drop in the contribution of gender to -0.22, capturing increased female labor force participation. Considering the period of Growth and Recession in more detail in Figure 7, we see that labor quality growth rose steadily during the period, but declined slightly in 1995-2000 relative to the Long Slump of 1973-1995 as a consequence of a jump in labor force participation. The drastic decline in the gender contribution during the Great Recession period 2007-2012 reflects the fact that unemployment rates rose much more sharply for men than for women.

The change in the educational attainment of workers is the main driver of changes in labor quality, as shown in Figure 8A. In 1947 only 6.6% of the US work force had four or more years of college. By 1973 this proportion had risen to 14.5% and by 1991 to 24.8%. There was a change in classification in 1992 from years enrolled in school to years of schooling completed.
By 2012 32.7% of US workers had a BA degree or higher. The fall in the share of workers with lower educational attainment accelerated during the Great Recession.

Figure 8B shows that educational attainment of the 25-34 age group improved dramatically between 1947 and 1995, followed by a pause during the Investment Boom of 1995-2000 and the Jobless Growth period of 2000-07. During the Great Recession, the less-educated workers had much higher unemployment rates and the average educational attainment of workers rose. If less-educated workers return to the participation rates of 2007, improvement in the overall educational attainment of the 25-34 group will be modest with only a slight increase in the share of workers with MA degrees or better and no increase for people with some college or BA degrees.

Figure 8C gives participation rates of males and females for two age groups, 25-34 years old and 45-54 years old. Better-educated workers are much more likely to be employed for both genders and both age groups. Male workers with BA's have participation rates between 0.90 and 0.95 for all years except the recessions. Participation rates for males with high school diplomas are in the 0.80-0.85 range. There is no strong trend in the rates for the BA's and MA+'s until 2007. The Investment Boom of 1995-2000 drew in many less-educated and young workers, raising their participation rates. Since the 2000, participation rates have fallen for the less-educated and these rates have declined further during the Great Recession, beginning in 2007.

Although the decline in aggregate labor force participation is widely discussed, on employment participation rates by gender, age, and educational attainment like those presented in Figure 8C have not been available until now. Non-participation has been included in a model of employment and unemployment by Kory Kroft, Fabian Lange, Matthew J. Notowidigo, and Lawrence F. Katz.[5] This model has been elaborated by Alan B. Krueger, Judd Cramer, and David Cho (2014).[6]

The modeling of non-participation along with employment and unemployment could be extended to include a more detailed breakdown of alternatives to employment for members of the working age population. These might include disability status and increased participation in welfare programs. Both of these increased as a proportion of the working age population during the Great Recession due to relaxation of requirements for participation. Labor force participation may have been adversely affected by extended benefit periods for the unemployed, which have now expired, and lower income requirements for receipt of food stamps.

The increase in the "college premium," the difference between wages earned by workers with college degrees and wages of those without degrees, has been widely noted. In Figure 9 we plot the compensation of workers by educational attainment, relative to those with a high school diploma (four years of high school). We see that the four-year college premium was stable at about 1.4 in the 1960s and 1970s, but rose to 1.6 in 1995 and 1.8 in 2000. The college premium stalled throughout the 2000s. The Masters-and-higher degree premium rose even faster than the BA premium between 1980 and 2000 and continued to rise through the mid-2000s.

[5] Kory Kroft, Fabian Lange, Matthew J. Notowidigo, and Lawrence F. Katz (2015), "Long-Term Unemployment and the Great Recession: The Role of Composition, Duration Dependence, and Non-Participation," *Journal of Labor Economics*, forthcoming.
[6] Alan B. Krueger, Judd Cramer, and David Cho (2014), "Are the Long-Term Unemployed on the Margins of the Labor Market," *Brookings Economic Papers*, Spring, pp. 229-300.

A possible explanation for the rise in relative wages for college workers with a rising share of these workers is that they are complementary to the use of information technology.[7] The most rapid growth of the college premium occurred during the 1995-2000 boom when IT capital made its highest contribution to GDP growth. Our industry-level view of postwar U.S. economic history allows us to consider also the role of changing industry composition in determining relative wages.

Table 1 gives the workforce characteristics by industry for 2010. The industries with the higher share of college-educated workers are also those that expanded rapidly – computer and electronic products, publishing (including software), information and data processing, and computer systems design, as well as industries that use these IT products and services – securities and commodity contracts, legal services, professional and technical services, and educational services. Not all sectors that expanded faster than average, such as retail trade and truck transportation, are dominated by highly educated workers. However, in declining sectors like mining, primary metals, and textiles the work force consists predominantly of less-educated workers.

After educational attainment the most important determinant of labor quality is the age of the worker. We have noted that the entry of the baby boomers into the labor force contributed negatively to labor quality growth during 1947-73 and that the aging of these workers contributed positively after 1973. We show the relative wages of the different age groups, relative to the wages of the 25-34 group, in Figure 10. The wages of the prime age group, 45-54, rose steadily relative to the young from 1.11 in 1970 to 1.41 in 1994. During the peak of the Information Age, the wages of the younger workers surged and the prime-age premium fell to 1.32.

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[7] See Claudia Goldin and Lawrence F. Katz (2008), *The Race between Education and Technology*, Cambridge, MA, Harvard University Press, for more details and historical background.

The wage premium of the 35-44 and 55-64 groups shows the same pattern as the premium of prime age workers, first rising relative to the 25-34 year olds, then falling or flattening out during the IT boom. The wage premium of the oldest workers is the most volatile but showed a general upward trend throughout the postwar period 1947-2012. The share of workers aged 65+ has been rising steadily since the mid-1990s during a period of large swings in the wage premium. The relative wages of the very young, 18-24, has been falling steadily since 1970, reflecting the rising demand for education and experience.

Sources of U.S. Economic Growth

In *Information Technology and the American Growth Resurgence* Jorgenson, Ho, and Stiroh (2005) have analyzed the economic impact of IT at the aggregate level for 1948-2002 and the industry level for 1977-2000. They have also provided a concise history of the main technological innovations in information technology during the postwar period, beginning with the invention of the transistor in 1947. Jorgenson, Ho, and Samuels (2012) have converted the industrial classification to NAICS and updated and extended the data to cover 70 industries for the period 1960-2007.

The NAICS industry classification includes the industries identified by Jorgenson, Ho, and Samuels (2014) 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 (2014) have classified industries as IT-using if the intensity of IT capital input is greater than the median for all U.S. industries that do not produce IT equipment, software and services. We classify all other industries as Non-IT.

Value added in the IT-producing industries during 1947-2012 is only 2.5 percent of the US economy, while value added in the IT-using industries is 47.5 percent with value added in the Non-IT industries accounting for the remaining fifty percent. The IT-using industries are mainly in trade and services and 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. We begin by discussing the results for the IT-producing sectors, now defined to include the two IT-service sectors.

Figure 11 reveals a steady increase in the share of IT-producing industries in the growth of 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 12 decomposes the growth of value added for the period 1995-2012. 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 also revived during the Investment Boom and declined substantially during the Jobless Recovery and the Great Recession.

Figure 13 gives the contributions to value added for the 65 individual industries over the period 1947-2012. In order to assess the relative importance of productivity growth at the industry level as a source of US economic growth, we note that the growth rate of aggregate productivity as a weighted average of industry productivity growth rates, using the ingenious weighting scheme of Evsey Domar (1961)[8]. The Domar weight is the ratio of the industry's gross output to aggregate value added and they sum to more than one. This reflects the fact that an increase in the rate of growth of the industry's productivity has a direct effect on the industry's output and a second indirect effect via the output delivered to other industries as intermediate inputs.

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[8]The formula is given in Jorgenson, Ho and Stiroh (2005), equation 8.34

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 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 input growth rates. Aggregate capital and labor inputs then grow more rapidly than 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 14 shows that the contributions of IT-producing, IT-using, and Non-IT industries to aggregate productivity growth are similar in magnitude for the period 1947-2012. 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 the Postwar Recovery, but became the predominant source of U.S. productivity growth during the Long Slump, 1973-1995, and increased considerably during the period of Growth and Recession, 1995-2012.

The IT-using industries contributed substantially to U.S. economic growth during the Postwar Recovery, but this contribution disappeared during the Long 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 1947-2012 and for each of the sub-periods. The contribution of reallocation of labor input was negligible for the period as a whole. During the Long Slump and the period of Growth and Recession, the contribution of the reallocation of labor input was slightly negative.

Considering the period of Growth and Recession in more detail in Figure 15, 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, 2000-2007, and 2007-2012 – despite the sharp 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 period of Jobless Growth, but became negative during the Great Recession. The Non-IT industries contributed positively to productivity growth during the Investment Boom of 1995-2000, but these contributions were almost negligible during the Jobless Recovery and only slightly positive during the Great Recession.

Figure 16 gives the contributions of each of the 65 industries to productivity growth for the postwar period. Wholesale and retail trade, farms, computer and peripheral equipment, and semiconductors and other electronic components were among the leading contributors to U.S. productivity growth during the postwar period. About half the 65 industries made negative contributions to aggregate productivity. These include non-market services, such as health, education, and general government, as well as resource industries affected by resource depletion, such as oil and gas extraction and mining. Other negative contributions reflect the growth of barriers to resource mobility in product and factor markets due, in some cases, to more stringent government regulations. The contributions of college-educated and non-college-educated workers to U.S. economic growth are given by the relative shares of these workers in the value of output, multiplied by the growth rates of their labor input. 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.

Figure 17 shows that contribution of college-educated workers predominated in the growth of labor input during the postwar period 1947-2012. This contribution jumped substantially from the Postwar Recovery period 1947-1973 to the period 1973-1995 of the Long Slump. The contribution of non-college workers predominated during the Postwar Recovery, but declined steadily and almost disappeared during the period 1995-2012 of Growth and Recession.

Figure 17 shows that capital input was the predominant source of U.S. economic growth for the postwar period 1947-2012, accounting for 1.62 percent of U.S. economic growth of 3.05 percent. Capital input was also predominant during the Postwar Recovery, the Long Slump, the period of Growth and Recession. Considering the period of Growth and Recession in greater detail, Figure 18 reveals that the contribution of capital input was about half of U.S. economic growth during the Investment Boom and increased in relative importance as the growth rate fell in the Jobless Recovery and again in the Great Recession.

Figure 17 provides considerably more detail on important changes in the composition of the contribution of capital input. For the postwar period as a whole the contribution of R&D to U.S. economic growth was considerably less than the contribution of IT, but other forms of capital input greatly predominated. While the contribution of R&D exceeded that of IT during the Postwar Recovery, the contribution of IT grew rapidly during the Long Slump and jumped to nearly half the contribution of capital input during the period of Growth and Recession. By contrast the contribution of R&D shank during both periods and became relatively insignificant. Figure 18 reveals that the contribution of capital input peaked during the Investment Boom, declined during the Jobless Recovery, and collapsed during the Great Recession, but the relative importance of IT remained the same throughout the period of Growth and Recession.

Figure 18 reveals that all of the sources of economic growth contributed to the U.S. growth resurgence after 1995, relative to the Long Slump represented in Figure 17. Both IT and Non-IT investment contributed substantially to growth during the Jobless Recovery of 2000-2007, but the contribution of labor input dropped precipitously and the contribution of non-college workers became slightly negative. The most remarkable feature of the Jobless Recovery was the continued growth in productivity, indicating an ongoing surge of innovation.

Both IT and Non-IT investment continued to contribute substantially to U.S. economic growth during the Great Recession period 2007-2012, while the contribution of R&D investment remained insignificant. Productivity growth almost disappeared, 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. These trends represent increased rates of substitution of capital for labor and college-educated workers for non-college workers.

Future U.S. Economic Growth

Our contribution to the projection of future U.S. economic growth is to provide highly disaggregated projections of the components of the U.S. labor force, including hours worked and labor quality growth. Given the uncertainty of the projections of participation rates and labor quality growth, as well as growth of capital quality and TFP, we construct three alternative projections for the period 2012-2022. We present our Base Case, Low Growth and High Growth projections of future growth in U.S. GDP for the period 2012-2022 in Figures 19, 20 and 21.

We use common assumptions for all three projections for the following variables: The capital share and reproducible stock share are set to the 1947-2012 averages. The shares of nominal

GDP due to IT- producers and IT-users are the 2000-2012 averages to reflect the importance of IT in the later years of the sample relative to the earlier period. More details are provided in the Appendix.

Base Case

Our base case allows participation rates and weekly hours for each sex-age-education group to revert to 2007 levels after 10 years. This excludes the relatively high participation rates of the late 1990s and the relatively low participation rates since the Great Recession of 2007-2009. Due to the re-entry of the less-educated workers, we project that hours will grow at 1.53% per year over the next decade and that labor quality will increase at only 0.04% per year. This projected growth of labor quality is significantly lower than labor quality growth during the historical period 1947-2012 of about 0.43% per year. It is also considerably lower than the 0.46% per year growth during 2000-2012, when participation rates for the less-educated workers declined.

In the Base Case we assume that capital quality and TFP growth for the next ten years will equal their averages over 1995-2012. The 1995-2012 period includes the IT Boom of the late 1990s with its rapid capital accumulation of IT assets and relatively rapid TFP growth. The Jobless Recovery of 2000-2007 had strong TFP growth but relatively slow improvements in capital quality. The Great Recession and the ongoing recovery of 2007-2012 had weak TFP growth and a small decline in capital quality. By taking an average over these three episodes, we capture the variation in rates of technical change this period.

The growth rate of capital quality during 1995-2012 of about 0.86% per year is only slightly below the average of 0.89% per year for the entire period 1947-2012. We assume that TFP growth in the IT-producing sector is 5.0% per year, compared to 4.96% for the 1990-2012 period and

2.76% over the postwar period. The rapid growth in TFP in the IT-producing sector reflects ongoing innovation and improvements in product quality discussed in more detail below.

The growth of TFP in the IT-producing sector contributes 0.29% per year to growth in labor productivity in the projection period. We assume that TFP growth in the IT-using sector will be 0.47% per year, implying a contribution of 0.17% per year to labor productivity growth over the next 10 years. This exceeds the contribution during 1990-2012 of 0.09% per year, reflecting more rapid TFP growth and higher value share. Finally, we assume that the remaining Non-IT sector of the economy will contribute 0.01% to labor productivity growth, compared to 0.06% over 1990-2012.

Our Base Case projection of labor productivity growth of 1.05% per year over the next ten years is markedly lower than the 1.76% per year growth during 1990-2012 and 2.02% over the postwar period. The differences are due to the interaction between the contributions of education to labor quality growth and the growth of hours worked. In our Base Case projection labor quality growth is very modest, due to the strong growth of hours work. This reflects the re-entry of less-educated workers during the continuing economic recovery. Rapid growth in hours worked also implies a relatively low contribution from capital deepening, 0.56% per year in the Base Case versus 1.02% in the 1990-2012 period.

Adding our projected growth rates in hours worked of 1.53% per year and 1.05% in labor productivity, we project GDP growth of 2.58% over the next ten years. This is a modest acceleration from the growth rate of 2.38% per year during over 1990-2012. This acceleration reflects the rapid growth in hours worked, offsetting the relatively slow growth in labor productivity. We conclude by emphasizing that we do not present a model of the determinants of participation in employment, but rely on extrapolations of historical data.

Low Growth Case.

Our first alternative assumption to the Base Case is that participation rates for each sex-age-education group remain at 2012 values with no further recovery from the sharp decline during the Great Recession of 2007-2009. This Low Growth Case embodies the “new normal” hypothesis that the Great Recession has had very persistent effects on the labor market. Under this assumption, we project hours to grow at 0.57% per year over the next decade, and labor quality to grow at 0.21% per year. Our projected growth of labor quality is 0.21% per year, significantly lower than growth during the postwar period 1947-2012 of 0.43% per year.

We assume that capital quality and TFP growth for the next ten years will equal their averages over 1973-2012, a period which includes the Long Slump, the IT Boom, the Jobless Recovery and the Great Recession. By including the Long Slump, we dampen the growth rates in this low scenario. Taking averages over 1973-2012 yields a capital quality growth rate of about 0.90% per year, approximately equal to the 0.89% per year over the entire postwar period.

We further assume that TFP in the IT-producing sector grows at 4.45% per year, compared to 4.96% for the 1990-2012 sub-period and 2.76% over the entire postwar period. Using the 2000-2012 average share of the IT-producing sector in output, we obtain a contribution of TFP growth in the IT-producing sector to growth of labor productivity of 0.26 percentage points. The growth of TFP in the IT-using sector is assumed to be 0.22% per year, implying a contribution of 0.08% per year over the next 10 years, about equal to the contribution over the 1990-2012 period of 0.09% per year. Finally, we assume that TFP from the Non-IT remainder of the economy will contribute -0.02% to labor productivity growth, compared to 0.06 percentage points for 1990-2012.

The projected labor productivity growth of 1.15% per year for the next ten years in the Low Growth Case is markedly slower than the 1.76% per year growth over the 1990-2012 period and

2.02% per year growth over the entire postwar period. However, this growth rate of labor productivity is higher than the 1.05% in the Base Case. While this might appear to be puzzling, it is consistent with the assumption that participation rates remain at 2012 levels, so that the less-educated workers who dropped out during the Great Recession will not return.

By adding the projected growth rate in hours worked of 0.57% per year to the 1.15% growth in labor productivity, the Low Growth Case projects output growth at 1.72% over the next ten years. This is a substantial deceleration from the growth rate of 2.38 percent during 1990-2012. The difference is explained by the implied capital deepening contribution of only 0.72 in the projection, compared with 1.02 percent during 1990-2012.

High Growth Case.

For the High Growth Case we assume that participation rates for each sex-age-education group to revert to 2000 levels in 10 years. This permits participation rates to recover to levels during the IT Investment Boom that ended in 2000. This was a period of high participation rates, especially among the young and less-educated. Under this assumption hours worked grow at 1.83% per year over the next decade, and labor quality grows at the negative rate of 0.07% per year. This projected growth of labor quality is significantly lower than growth during the postwar period 1947-2012 of 0.43% per year and 0.46% per year during 2000-2012.

For the High Growth Case we assume that growth in capital quality and TFP for the next ten years will equal their averages over 1995-2007. This includes the Investment Boom and the Jobless Growth periods, but excludes the Long Slump and the Great Recession as temporary lulls in economic growth. Taking averages over 1995-2007 yields a capital quality growth rate of about 1.27% per year, significantly higher than the 0.89% per year growth rate over the entire postwar period.

We assume that TFP in the IT-producing sector grows at 5.94% per year, compared to 5.0% in the Base Case. This translates to a TFP contribution to growth in labor productivity of 0.34 percent. The growth of TFP in the IT-using sector is set at 0.70% per year, implying a contribution of 0.25% per year over the next 10 years, compared to 0.17 in the Base Case. Finally, we assume that TFP growth in the remainder of the economy will contribute zero to labor productivity growth, close to the 0.06% over 1990-2012.

Combining these assumptions, projected labor productivity growth is 1.36% per year over the next ten years. This High Growth scenario is significantly slower than the 1.76% per year growth over 1990-2012. The most significant difference is the decline in projected labor quality as the young and less-educated workers re-enter the labor force. A second difference is substantially slower capital deepening.

By adding our projected growth rate in hours worked of 1.83% per year to the 1.36% projected growth in labor productivity, the High Growth Case projects output growth at 3.20% over the next ten years. This large acceleration in growth relative to 1990-2012 is mainly due to the strong growth of hours for people returning to the work force. It is important to recall that our assumptions about participation rates differ by demographic group, so the growth in hours reflects the impacts of the Great Recession on different types of workers.

Alternative Projections.

Byrne, Oliner, and Sichel (2013) provide a recent survey of contributions to the debate over prospects for future U.S. economic growth. Tyler Cowen (2011) presents a pessimistic outlook in his book, *The Great Stagnation*: *How America Ate All the Low-Hanging Fruit, Got Sick, and Will (Eventually) Feel Better*. His views are supported by Robert Gordon (2012, 2014), who analyzes six headwinds facing the US economy, including the end of productivity growth in IT-producing industries. Cowen (2013) expresses a more sanguine view in his book, *Average is Over: Powering America Beyond the Age of the Great Stagnation.*

Gordon's pessimism about the future of IT is forcefully refuted by Erik Brynjolfsson and Andrew McAfee (2014) in the *Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies.*[9] Martin Baily, James Manyika, and Shalabh Gupta (2013) summarize an extensive series of studies of the technological prospects for American industries, including IT, conducted by the McKinsey Global Institute and summarized by Manyika, *et al.* (2011). These studies also present a more optimistic view.

John Fernald (2015) analyzes the growth of potential output and productivity before, during, and after the Great Recession and reaches the conclusion that half the shortfall in the rate of growth of output, relative to pre-recession trends, is due to slower growth in potential output. Byrne, Oliner and Sichel present projections of future US productivity growth for the nonfarm business sector and compare their results with others, including Fernald and Gordon. They show that there is substantial agreement among the alternative projections.

Byrne, Oliner and Sichel provide detailed evidence on the recent behavior of IT prices. This is based on research at the Federal Reserve Board to provide deflators for the Index of Industrial Production. While the size of transistors has continued to shrink, performance of semiconductors devices has improved less rapidly, severing the close link that had characterized Moore's Law as a description of the development of semiconductor technology.[10] This view is supported by Unni Pillai (2011) and by the computer scientists John Hennessey and David Patterson (2012).[11]

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[9] Brynjolfsson and Gordon have debated the future of information technology on TED. See: http://blog.ted.com/2013/02/26/debate-erik-brynjolfsson-and-robert-j-gordon-at-ted2013/

[10] Moore's Law is discussed by Jorgenson, Ho, and Stiroh (2005), ch. 1.

[11] See John Hennessey and David Patterson (2012), Figure 1.16, p. 46. An excellent journalistic account of the slowdown in the development of Intel microprocessors is presented by John Markoff in the New York Times for September 27, 2015. See: http://www.nytimes.com/2015/09/27/technology/smaller-faster-cheaper-over-the-future-of-computer-chips.html .

Conclusions

Our industry-level data set 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 US economic growth. International productivity comparisons reveal similar patterns for the world economy, its major regions, and leading industrialized, developing, and emerging economies.[12] Studies are now underway to extend these comparisons to individual industries for the countries included in the World KLEMS Initiative.[13]

Conflicting interpretations of the Great Recession can be evaluated from the perspective of our new data set. We do not share the technological pessimism of Cowen (2011) and Gordon (2014), especially for the IT-producing industries. Careful studies of developments of semiconductor and computer technology show that the accelerated pace of innovation that began in 1995 reverted to the lower, but still substantial, rates of innovation in IT. This accounted for almost all of productivity growth during the Great Recession.

Our findings also contribute to an understanding of the future potential for US economic growth. Our new projections corroborate the perspective of Jorgenson, Ho, and Stiroh (2008), who showed that the peak growth rates of the US Investment Boom of 1995-2000 were not sustainable. However, our projections are more optimistic than those we presented earlier in Jorgenson, Ho, and Samuels (2014). While low productivity growth during the Great Recession will be transitory, productivity is unlikely to return to the high growth rates of the Investment Boom and the Jobless Recovery.

[12] See Jorgenson and Vu (2013).
[13] See Jorgenson (2012), "The World KLEMS Initiative," *International Productivity Monitor,* Fall, pp. 5-19.

Finally, we conclude that the new findings presented in this paper have important implications for US economic policy. Maintaining the gradual recovery from the Great Recession will require a revival of investment in IT equipment and software and Non-IT capital as well. Enhancing opportunities for employment is also essential. While this is likely to be most successful for highly-educated workers, raising participation rates for the less-educated workers and the young will be needed for a revival of U.S. economic growth.

Appendix: Projections.

We adapt the methodology of Jorgenson, Ho and Stiroh (2008) to utilize data for the 65 industries included in the U.S. National Income and Product Accounts. The growth in aggregate value added (Y) is an index of the growth of capital (K) and labor (L) services and aggregate growth in productivity (A):

(A1) $$\Delta \ln Y = \bar{v}_K \Delta \ln \mathrm{K} + \bar{v}_L \Delta \ln L + \Delta \ln A$$

To distinguish between the growth of primary factors and changes in composition, we decompose aggregate capital input into the capital stock (Z) and capital quality (KQ), and labor input into hours (H) and labor quality (LQ). We also decompose the aggregate productivity growth into the contributions from the IT-producing industries, the IT-using industries, and the Non-IT industries. The growth of aggregate output becomes:

(A2) $$\begin{aligned}\Delta \ln Y &= \bar{v}_K \Delta \ln Z + \bar{v}_K \Delta \ln KQ + \bar{v}_L \Delta \ln H + \bar{v}_L \Delta \ln LQ \\ &\quad + \bar{u}_{ITP} \Delta \ln A_{ITP} + \bar{u}_{ITU} \Delta \ln A_{ITU} + \bar{u}_{NIT} \Delta \ln A_{NIT}\end{aligned}$$

where the $\Delta \ln A_i$'s are productivity growth rates in the IT-producing, IT-using and Non-IT groups and the *u*'s are the appropriate weights. Labor productivity, defined as value added per hour worked, is expressed as:

(A3) $\Delta \ln y = \Delta \ln Y - \Delta \ln H$

We recognize the fact that a significant component of capital income goes to land rent. In our projections we assume that land input is fixed, and thus the growth of aggregate capital stock is:

(A4) $\Delta \ln Z = \bar{\mu}_R \Delta \ln Z_R + (1 - \bar{\mu}_R) \Delta \ln LAND = \bar{\mu}_R \Delta \ln Z_R$

where Z_R is the reproducible capital stock and $\bar{\mu}_R$ is the value share of reproducible capital in total capital stock.

We project growth using equation (A2), assuming that the growth of reproducible capital is equal to the growth of output, $\Delta \ln Y^P = \Delta \ln Z_R^P$, where the *P* superscript denotes projected variables. With this assumption, the projected growth rate of average labor productivity is given by:

(A5)
$$\Delta \ln y^P = \frac{1}{1 - \bar{v}_K \bar{\mu}_R} \times [\bar{v}_K \Delta \ln KQ - \bar{v}_K (1 - \bar{\mu}_R) \Delta \ln H + \bar{v}_L \Delta \ln LQ + \bar{u}_{ITP} \Delta \ln A_{ITP} + \bar{u}_{ITU} \Delta \ln A_{ITU} + \bar{u}_{NIT} \Delta \ln A_{NIT}]$$

We emphasize that this is a long-run relationship that removes the transitional dynamics related to capital accumulation.

To employ equation (A5) we first project the growth in hours worked and labor quality. We obtain population projections by age, race and sex from the U.S. Census Bureau[14] and organize the data to match the classifications in our labor database (8 age groups, 2 sexes). We read the 2010 Census of Population to construct the educational attainment distribution by age, based on the 1% sample of individuals for both the population and the employed persons. We use the micro-data in the Annual Social and Economic Supplement (ASEC) of the *Current Population Survey* to extrapolate the educational distribution for all years after 2010 and to interpolate between the 2000

[14] The projections made by the U.S. Census Bureau in 2012 are given on their web site: http://www.census.gov/population/projections/data/national/2012.html. The resident population is projected to be 420 million in 2060. We make an adjustment to give the total population including Armed Forces overseas.

and 2010 Censuses. This establishes the actual trends in educational attainment for the sample period.

Educational attainment derived from the 2010 Census shows little improvement for males compared to the 2000 Census with some age groups showing a smaller fraction with professional degrees. However, there was a higher proportion of females with BA degrees in 2010 than 2000. Our next step is to project the educational distribution for each sex-age group. For this purpose we use the historical improvements in educational attainment by these groups shown in Figure 8A.

Educational attainment of workers at the end of our sample period is dominated by the effects of the Great Recession. Less-educated workers experienced much higher unemployment rates than those with college degrees and had lower rates of participation. Second, improvement in the share of men with BA or MA+ degrees between 2000 and 2010 is modest, with some age groups falling behind. The improvement in women's education is more pronounced, especially in the older age groups, but there are also certain age groups of women that regressed.

Given these observations, we consider two alternative scenarios for educational improvement. In the first we assume continuing improvement for all ages. In a subsidiary case we assume that the educational attainment of men aged 18-60 has stabilized, so that there is no further improvement beyond the end of the sample. Let e_{saet} denote the distribution of the population of sex *s*, age group *a* over the educational groups *e*={less than HS, some HS, HS diploma, some college, BA, MA+}. Men over 60 years of age carry their educational attainment with them as they age, so that the educational distribution evolves according to:

(A.6) $e_{saet} = e_{sae,t-1}$ a=0,…60, s=male

$e_{saet} = e_{s,a-1,e,t-1}$ a=61,…,90+, s=male

For the women we assume that only those aged 18-35 have reached the maximum level in 2012:

(A.7) $e_{saet} = e_{sae,t-1}$ a=0,…35, s=female

$e_{saet} = e_{s,a-1,e,t-1}$ a=36,…,90+, s=female

In our principal education projection we allow a continuing rise in the share of people in each age group with BA's or MA's, based on the observed attainment in 2000 and 2010. The gain in the share with BA's and MA's among men during these 10 years was very small, even negative for some age groups. The gain among women is greater but not uniformly positive for all ages.

We establish a long-run target of maximum educational attainment for 2030 $e_{saet}^{\max}$ by assuming that there will be higher shares of people with BA degrees, MA degrees, Professional degrees or PhD degrees, with offsetting lower shares in the other categories (Associate degree, some college, HS diploma, some high school). We impose a target education-age profile that is changing smoothly for two groups of men – those with BA degrees and Professional degrees.

For men we assume that the increase in the share of BA's by 2030 is similar to the change between 2000 and 2010 for those between 24 and 44 years old. Given that the education-age profiles are somewhat erratic, this projection results in a somewhat uneven improvement by age. For the Professional degree target for men, we assume that the future increase in the share is similar to the improvement between 2000 and 2010 for ages 27 to 37. We apply similar rules for the Associate degrees, BA, MA, and PhD categories. We then apply a reverse rule that lowers the share of those with elementary school, some high school without diploma, and HS diploma.

We apply a similar procedure for women. We impose a smooth increase for the share of women with MA degrees that covers both the 2000 and 2010 lines. We also assume higher shares for Professional degrees and PhD's and offset this with shares of BA's and Associate degrees that are very close to the 2010 values, and lower shares for high school diploma and lower categories.

After establishing the $e_{saet}^{\max}$ target for 2030, we interpolate the 2013-2030 projected matrices linearly using the actual 2012 values and the target:

(A.8) $e_{saet}^{p} = \omega_t e_{saet}^{2012} + (1-\omega_t) e_{saet}^{\max}$ t=2013,…,2030

We apply this projected improvement to those aged less than 60, and allow those aged 61+ to carry their educational attainment as they age:

(A.9) $e_{saet} = e_{saet}^{p}$ a=0,…,60

$e_{saet} = e_{s,a-1,e,t-1}^{p}$ a=61,…,90+

Given that those aged *a* (>60) in 2012 has higher educational attainment than those aged *a-1* in 2012, this assumption generates a rising level of attainment in the population.

We assume that the educational attainment for men aged 39 or younger will be the same as the last year of the sample period, that is, a man who becomes 22 years old in 2022 will have the same chance of having a BA degree as a 22-year old man in 2012. For women, this cut-off age is set at 33. For men over 39 years old, and women over 33, we assume that they carry their education attainment with them as they age. For example, the educational distribution of 50 year olds in 2022 is the same as that of 40 year olds in 2012, assuming that death rates are independent of educational attainment. Since a 50-year-old in 2022 has a slightly higher attainment than and 51 year-old in 2020, these assumptions result in a smooth improvement in educational attainment that is consistent with the observed profile in the 2010 Census.

After projecting the population matrix by sex, age and education (POP_{saet}) for each year our next step is to project the employment and hours worked matrices by these dimensions. We use the employment, weekly hours, weeks per year and compensation matrices in 2010 described in

Jorgenson, Ho and Samuels (2014). The (employment) participation rate is the actual employed (*E*) divided by the population in each cell: $\pi_{saet} = \frac{E_{saet}}{POP_{saet}}$

The annual hours worked by group *sae* is then given by the projected population multiplied by the projected participation and the projected weekly hours (h_{saet}):

(A.10) $H_{saet} = h_{saet}\pi_{saet}POP_{saet} * 52$

Note that our employment participation rate is different from the official labor force participation rate which includes the unemployed.

The effective labor input in the projection period is calculated as a Tornqvist index of the hours worked weighted by the compensation share of each *sae* group. The compensation matrix is held fixed at the 2012 relative values for the projection period. The ratio of labor input to hours worked is our labor quality index.

The next step in employing equation (A5) is projecting capital quality. The growth rate of capital input is a weighted average of the stocks of various assets weighted by their shares of capital income. The ratio of total capital input to the total stock is the capital quality index which rises as the composition of the stock moves towards short-lived assets with high rental costs. The growth of capital quality during the period 1995-2000 was clearly unsustainable. For our base case projection we assume that capital quality grows at the average rate observed for 1995-2012. For the High Growth case we use the rate for 1995-2007. Finally, we use the rate for 1990-2012 for the Low Growth case.

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Table 1: Labor Characteristics by Industry, year 2010.

		% workers college educated	compen-sation ($/hour)	% of total hours; aged 16-35	% total hours; females	% Females college educated	% Males college educated
1	Farms	15.1	19.5	20.3	14.7	18.6	14.3
2	Forestry fishing and related activities	16.4	16.6	30.8	15.3	30.6	13.3
3	Oil and gas extraction	38.6	79.5	14.6	22.2	44.4	36.7
4	Mining except oil and gas	11.8	39.2	20.2	8.8	28.0	10.1
5	Support activities for mining	26.0	37.6	25.8	13.8	39.4	23.4
6	Utilities	24.0	64.0	22.0	23.4	28.6	22.6
7	Construction	14.0	31.6	33.9	8.9	24.8	12.8
8	Wood products	12.2	26.0	32.9	15.1	17.3	11.1
9	Nonmetallic mineral products	18.1	32.3	26.0	19.7	21.6	17.2
10	Primary metals	17.7	39.7	26.0	13.5	24.8	16.6
11	Fabricated metal products	15.2	32.2	27.7	17.7	15.9	15.0
12	Machinery	24.5	38.7	25.6	19.4	24.2	24.6
13	Computer and electronic products	62.3	56.7	31.0	30.3	54.2	66.0
14	Electrical equipment appliances	44.2	52.5	26.4	30.9	33.6	49.2
15	Motor vehicles bodies and parts	23.6	37.9	28.4	21.8	20.8	24.4
16	Other transportation equipment	31.4	50.6	22.6	17.3	30.9	31.7
17	Furniture and related products	15.6	26.3	31.5	24.3	17.4	15.0
18	Miscellaneous manufacturing	32.1	40.7	26.8	35.6	26.3	35.7
19	Food, beverage and tobacco	23.8	27.2	24.3	31.5	23.2	24.2
20	Textile mills and textile product mills	14.0	25.6	26.5	45.2	11.9	15.8
21	Apparel and leather products	17.6	27.0	27.4	55.9	15.4	20.9
22	Paper products	18.8	37.3	23.9	20.7	18.5	18.9
23	Printing and related support activities	22.0	29.5	28.7	32.2	23.1	21.4
24	Petroleum and coal products	32.9	81.5	17.7	17.4	45.2	30.0
25	Chemical products	49.5	54.1	27.4	35.2	49.1	50.3
26	Plastics and rubber products	16.4	30.7	30.2	28.5	11.4	18.5
27	Wholesale Trade	`	41.2	29.1	26.0	32.6	31.7
28	Retail Trade	15.8	23.0	35.4	42.0	14.4	17.3
29	Air transportation	38.2	49.5	28.6	35.9	36.7	39.1
30	Rail transportation	13.2	50.7	14.0	8.3	28.7	11.7
31	Water transportation	31.1	51.6	19.1	19.6	32.6	30.6
32	Truck transportation	8.6	28.0	24.6	11.1	14.4	7.8
33	Transit, ground passenger transportation	16.3	22.8	18.4	23.5	11.5	18.1
34	Pipeline transportation	32.8	65.6	17.5	18.4	45.6	29.6
35	Other transportation and support	19.7	33.5	34.1	20.7	22.3	19.0
36	Warehousing and storage	12.6	29.2	35.6	26.3	13.2	12.4
37	Publishing industries (includes software)	60.2	52.5	38.1	42.8	59.7	60.5
38	Motion picture and sound recording	45.9	46.4	47.9	31.6	48.8	44.3
39	Broadcasting and telecommunications	39.5	46.7	37.9	39.0	42.4	37.7
40	Information and data processing services	55.4	55.0	47.7	40.8	50.8	59.1
41	Fed Res banks, credit intermediation	42.4	42.1	36.5	60.1	30.3	62.8
42	Securities, commodity contracts	71.9	120.6	38.3	35.2	58.0	80.7
43	Insurance carriers	46.6	48.7	28.5	56.4	33.9	65.0

44	Funds, trusts & other financial vehicles	71.0	99.4	40.7	37.3	57.1	80.4
45	Real estate	40.6	31.1	18.6	46.6	36.1	45.1
46	Rental, leasing & lessors of intangibles	25.4	31.1	45.0	28.8	24.1	26.0
47	Legal services	65.5	57.5	29.0	53.1	46.3	90.6
48	Computer systems design	68.6	56.7	41.1	28.5	67.0	69.3
49	Misc. professional and technical services	65.3	46.9	31.1	42.3	58.9	70.6
50	Management of companies	53.4	62.2	28.9	51.4	39.8	69.4
51	Administrative and support services	20.1	24.8	37.7	40.4	23.2	17.9
52	Waste management	10.2	32.5	33.9	14.3	16.1	9.2
53	Educational services	64.2	28.8	27.5	65.9	64.2	64.2
54	Ambulatory health care services	38.8	39.2	27.5	74.2	30.8	66.6
55	Hospitals, Nursing and residential care	30.4	28.4	28.1	79.5	29.4	34.4
56	Social assistance	30.0	18.8	36.1	86.7	28.9	37.4
57	Performing arts, spectator sports	48.7	53.8	29.1	43.8	55.1	43.1
58	Amusements, gambling and recreation	21.7	20.1	39.4	41.0	22.2	21.4
59	Accommodation	18.6	22.1	35.8	52.7	16.3	21.3
60	Food services and drinking places	11.1	14.8	53.5	47.9	9.9	12.2
61	Other services except government	17.9	25.7	26.7	64.8	18.8	19.3
62	Federal General government	52.0	63.3	19.5	54.6	49.6	54.9
63	Federal Government enterprises	19.6	42.0	14.5	34.6	20.0	19.3
64	S&L Government enterprises	29.9	40.9	25.4	40.2	28.9	30.7
65	S&L General Government	48.6	36.3	23.5	61.2	48.6	50.6

Notes: "College educated" workers are those with BA or BA+

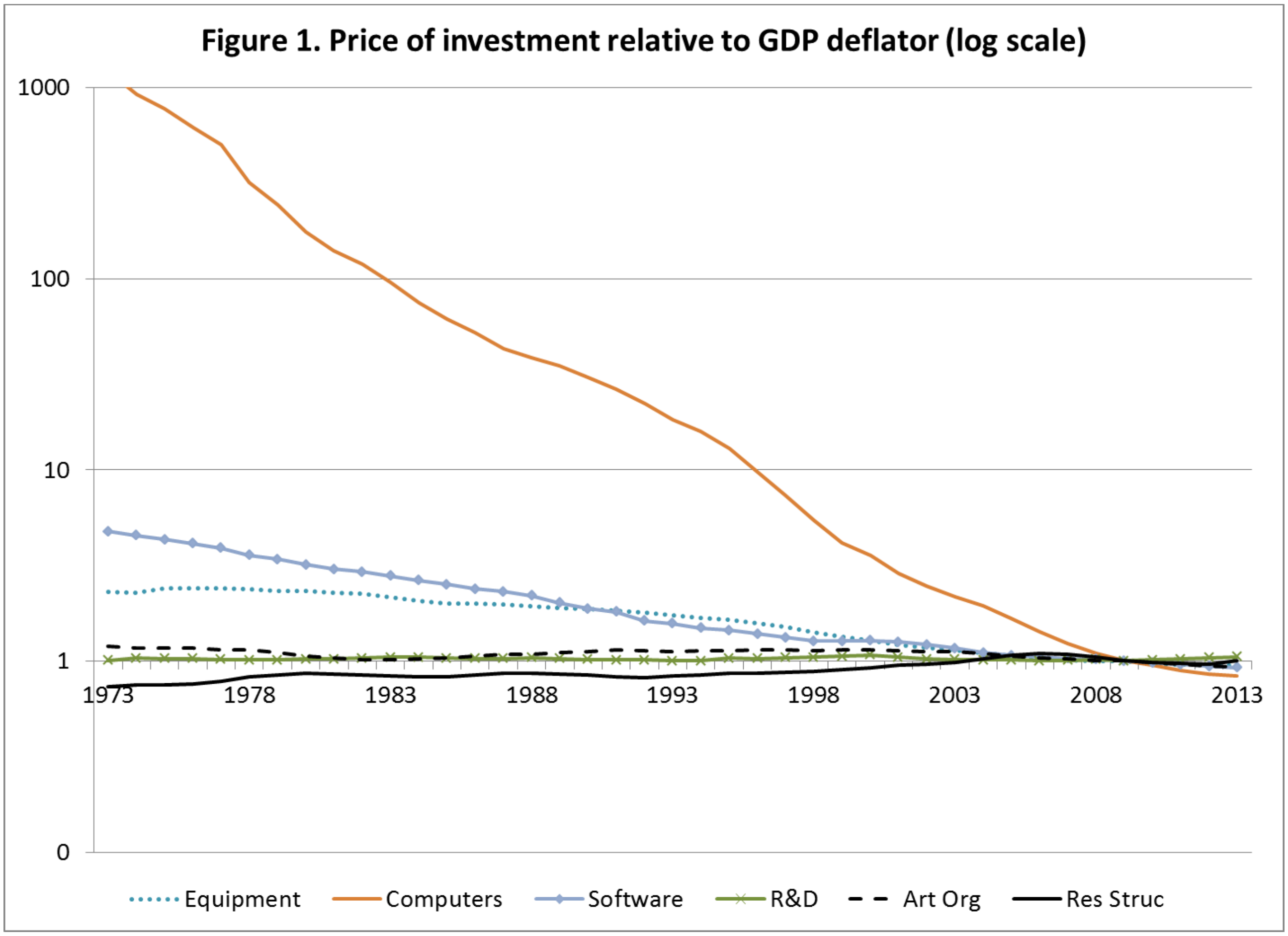


Figure 1. Price of investment relative to GDP deflator (log scale)
1000
100
10
1
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
Equipment
Computers
Software
R&D
Art Org
Res Struc

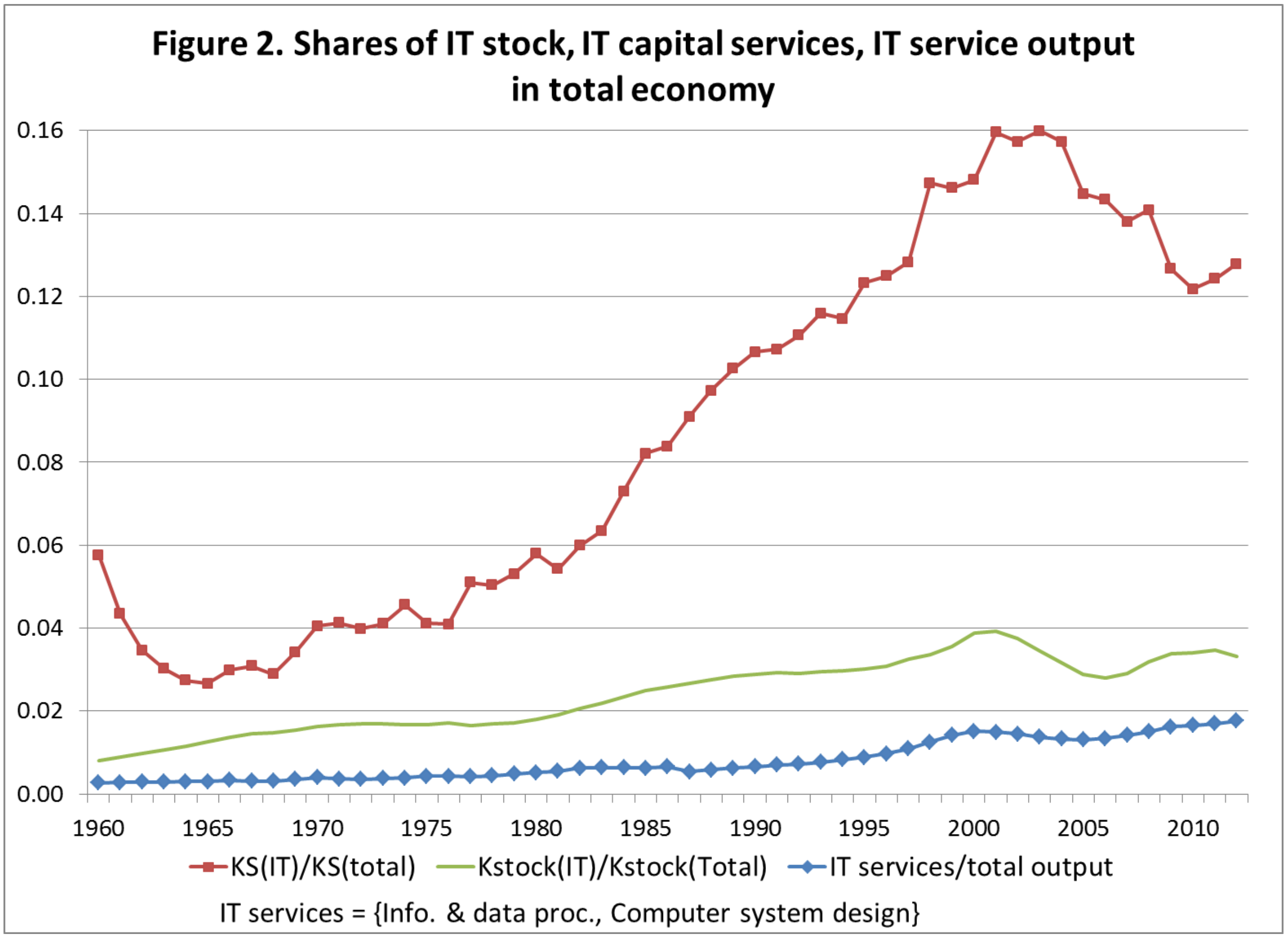


Figure 2. Shares of IT stock, IT capital services, IT service output in total economy
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
KS(IT)/KS(total)
Kstock(IT)/Kstock(Total)
IT services/total output
IT services = {Info. & data proc., Computer system design}

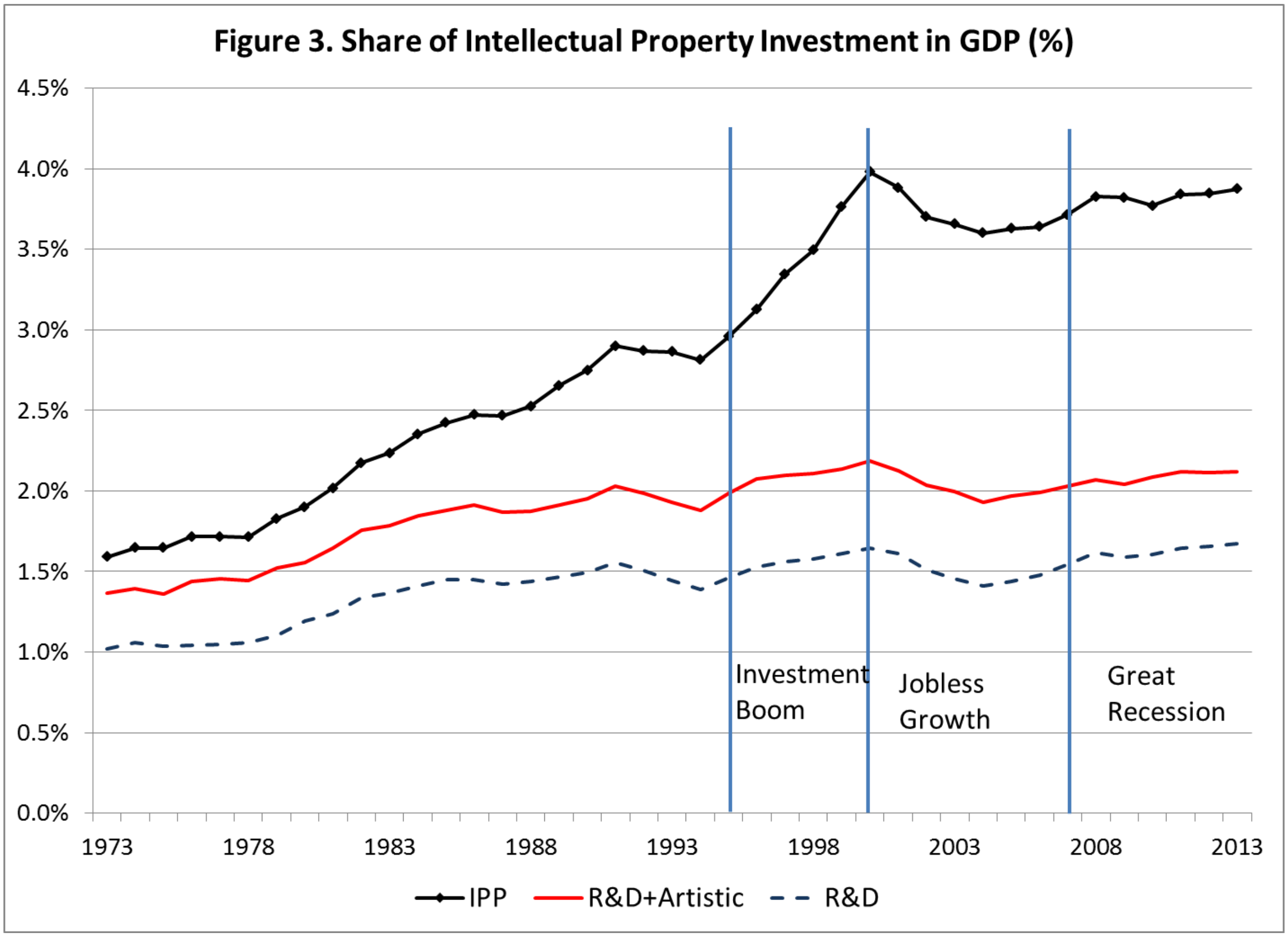
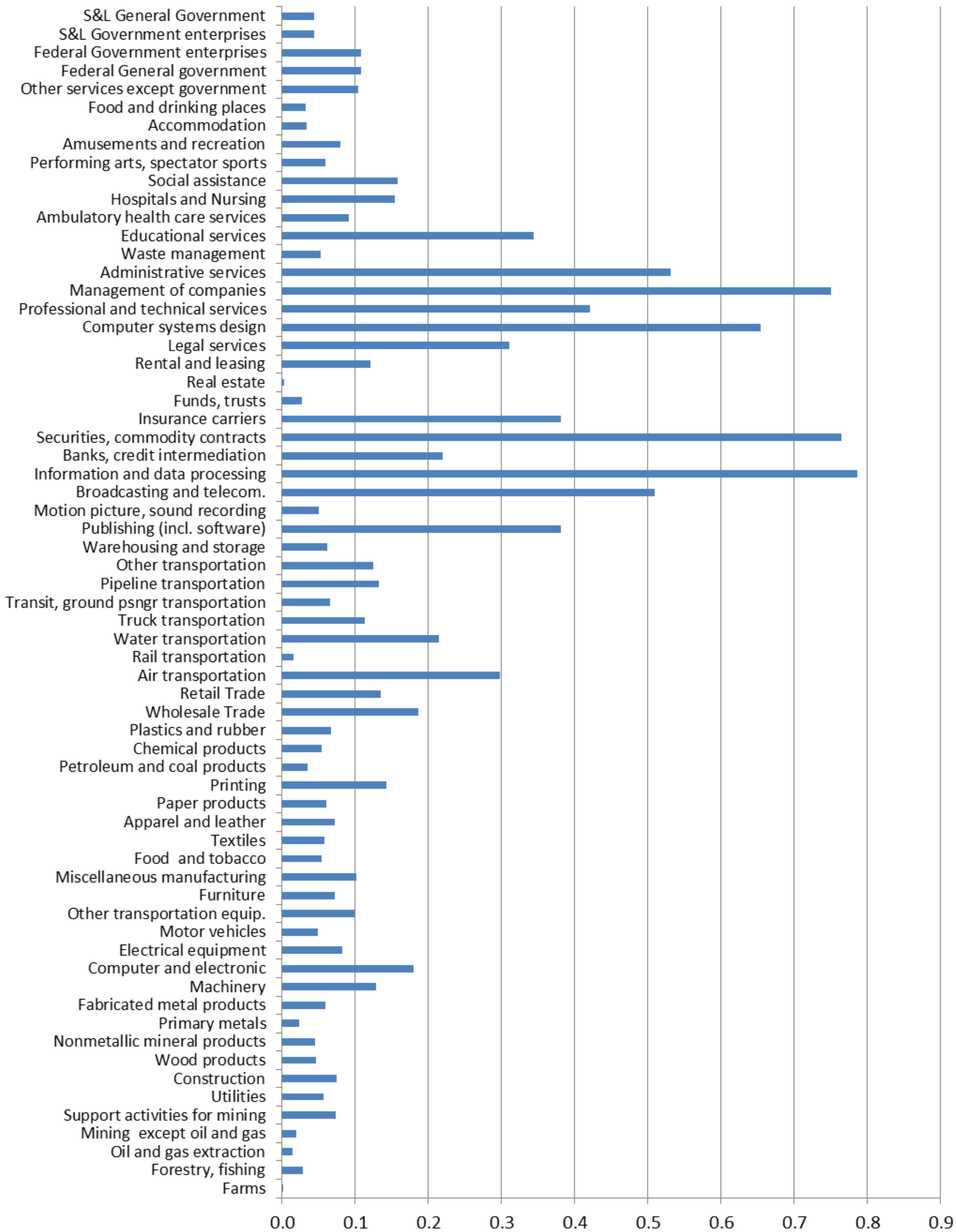


Figure 3. Share of Intellectual Property Investment in GDP (%)
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
1973
1978
1983
1988
1993
1998
2003
2008
2013
Investment Boom
Jobless Growth
Great Recession
IPP
R&D+Artistic
R&D

Figure 4. Share of IT capital services in total capital, 2005



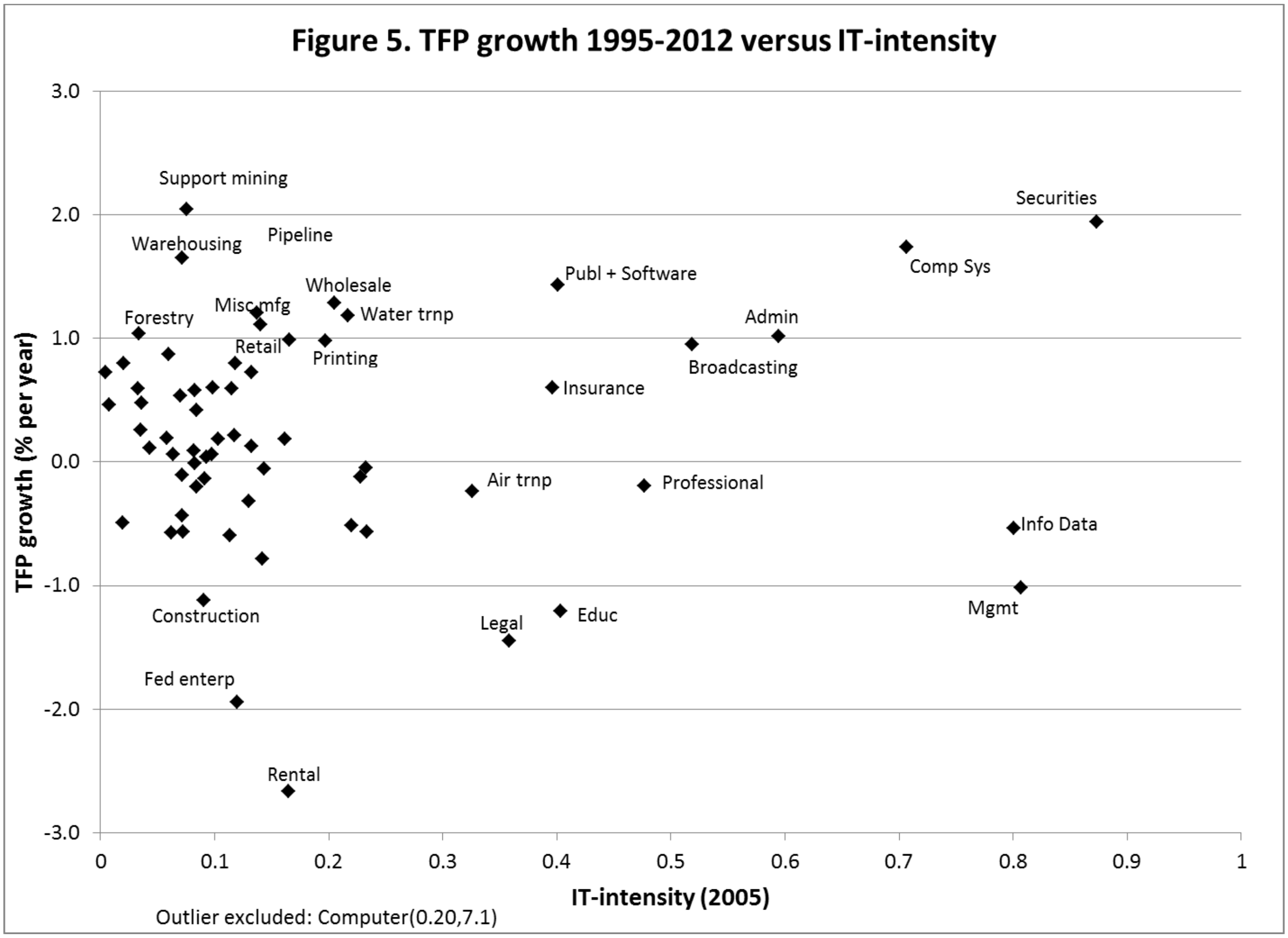


Figure 5. TFP growth 1995-2012 versus IT-intensity
TFP growth (% per year)
IT-intensity (2005)
Outlier excluded: Computer(0.20,7.1)
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Support mining
Warehousing
Pipeline
Wholesale
Misc mfg
Water trnp
Forestry
Retail
Printing
Publ + Software
Insurance
Admin
Broadcasting
Securities
Comp Sys
Air trnp
Professional
Info Data
Mgmt
Construction
Legal
Educ
Fed enterp
Rental

Figure 6. Contribution of education, age and gender to labor quality

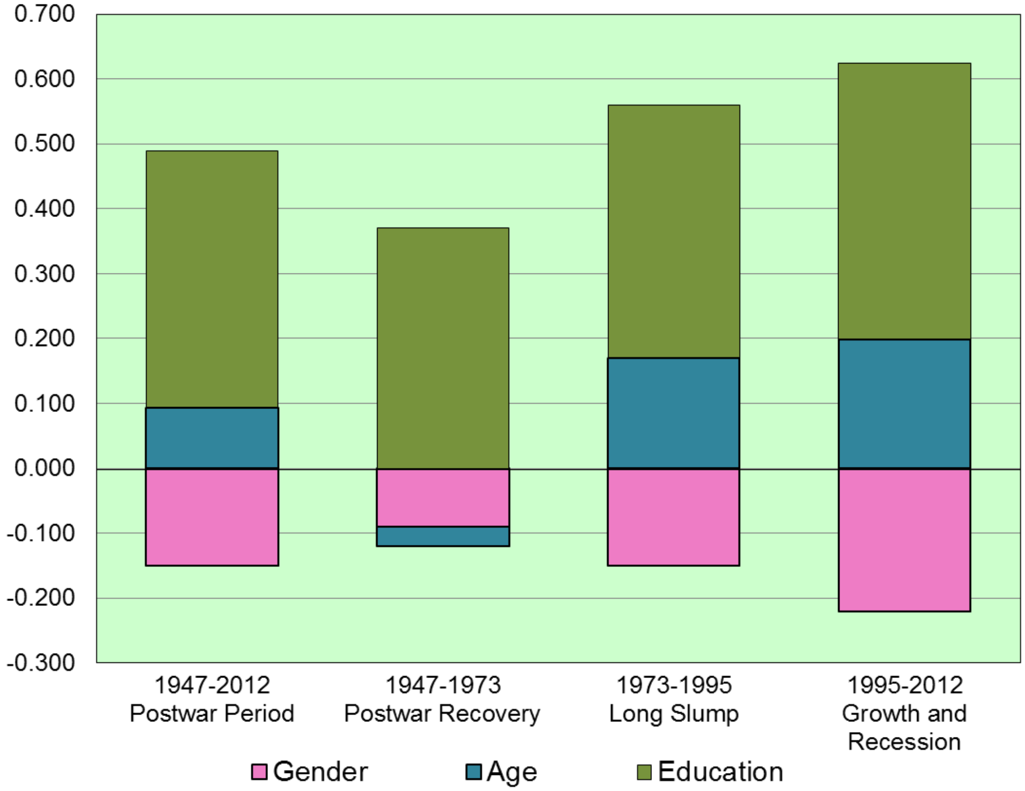


Figure 7. Contribution of education, age and gender to projected labor quality

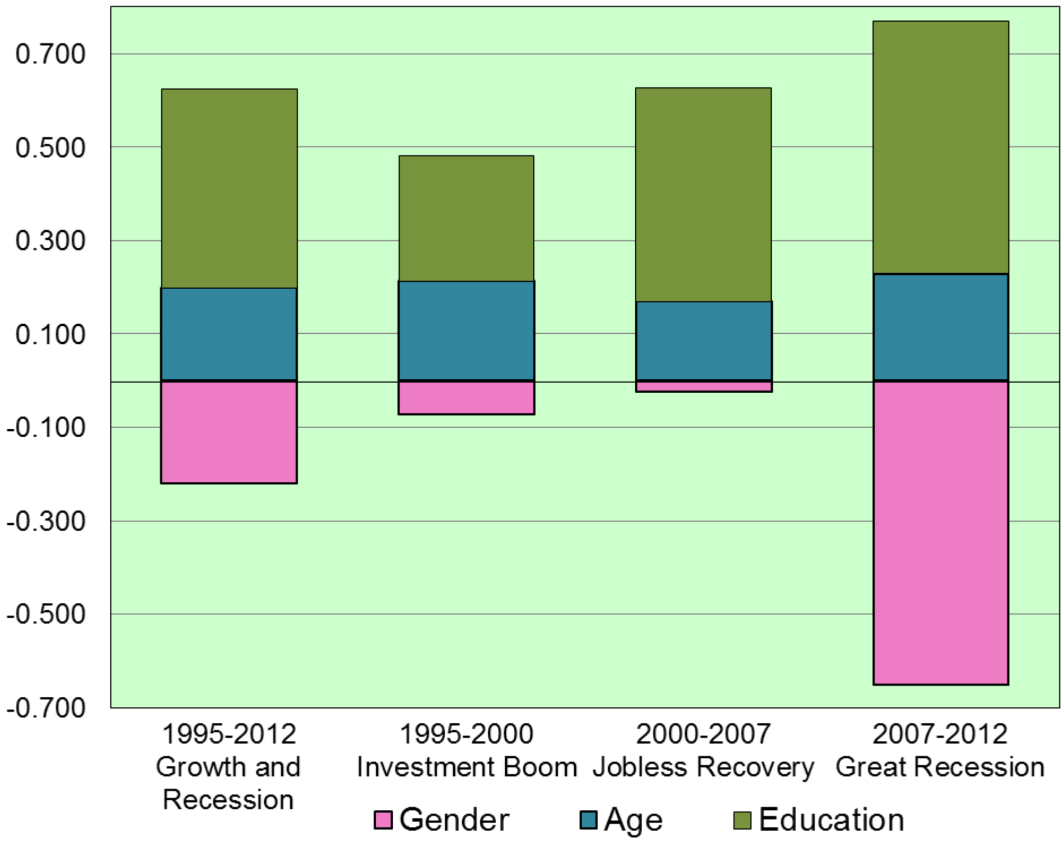


Figure 8A. Distribution of education attainment of work force

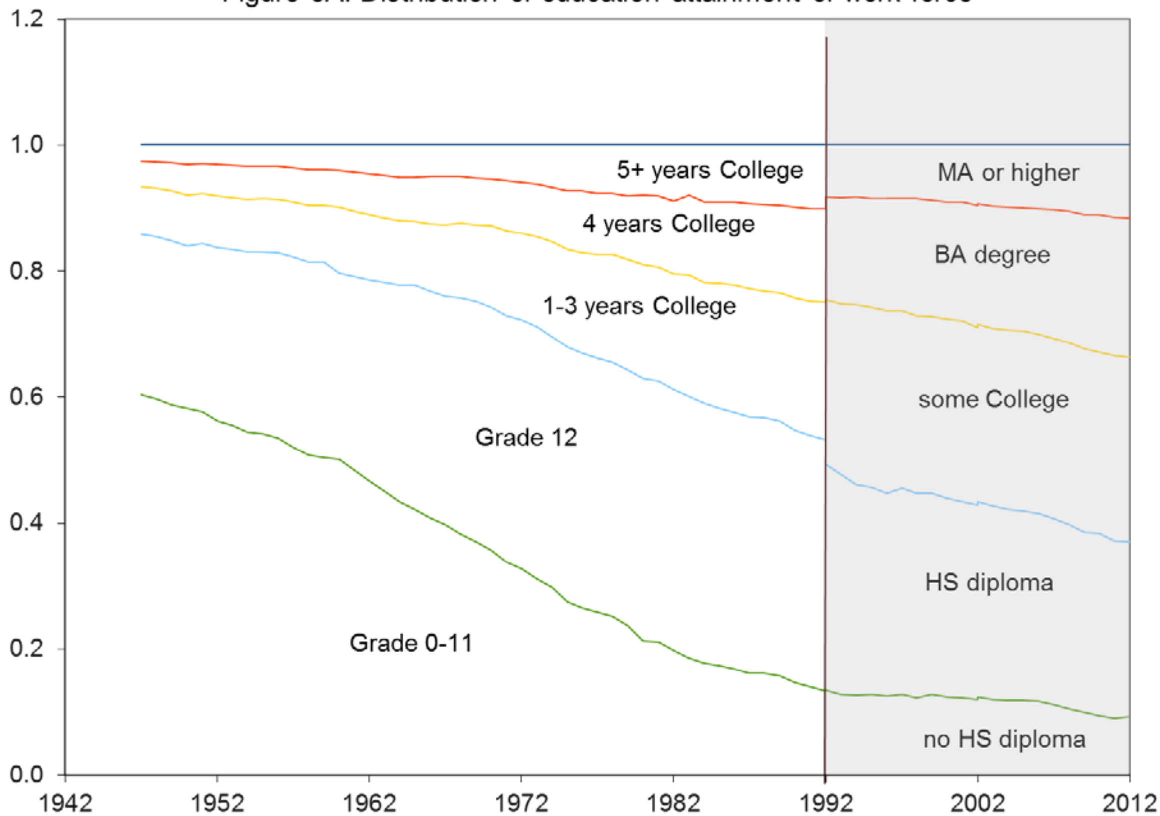


Figure 8B: Distribution of education attainment of workers aged 25-34

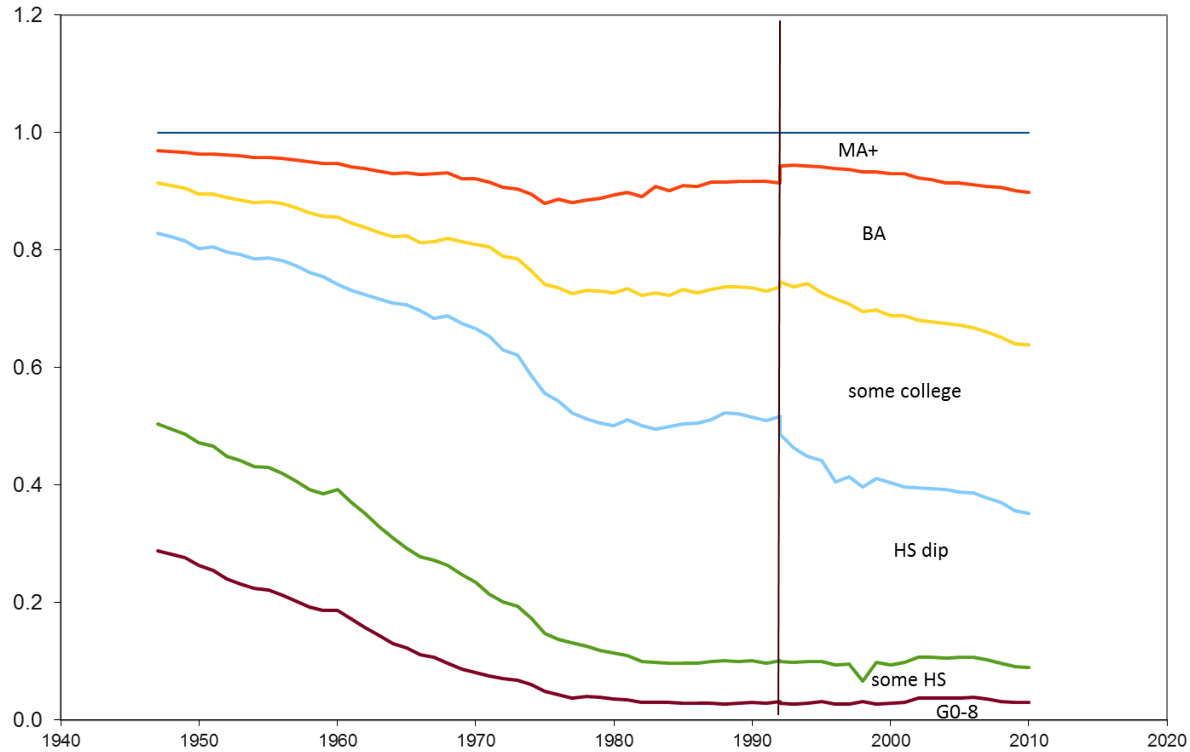


Figure 8C. Employment Participation Rates by Gender, Age, and Education

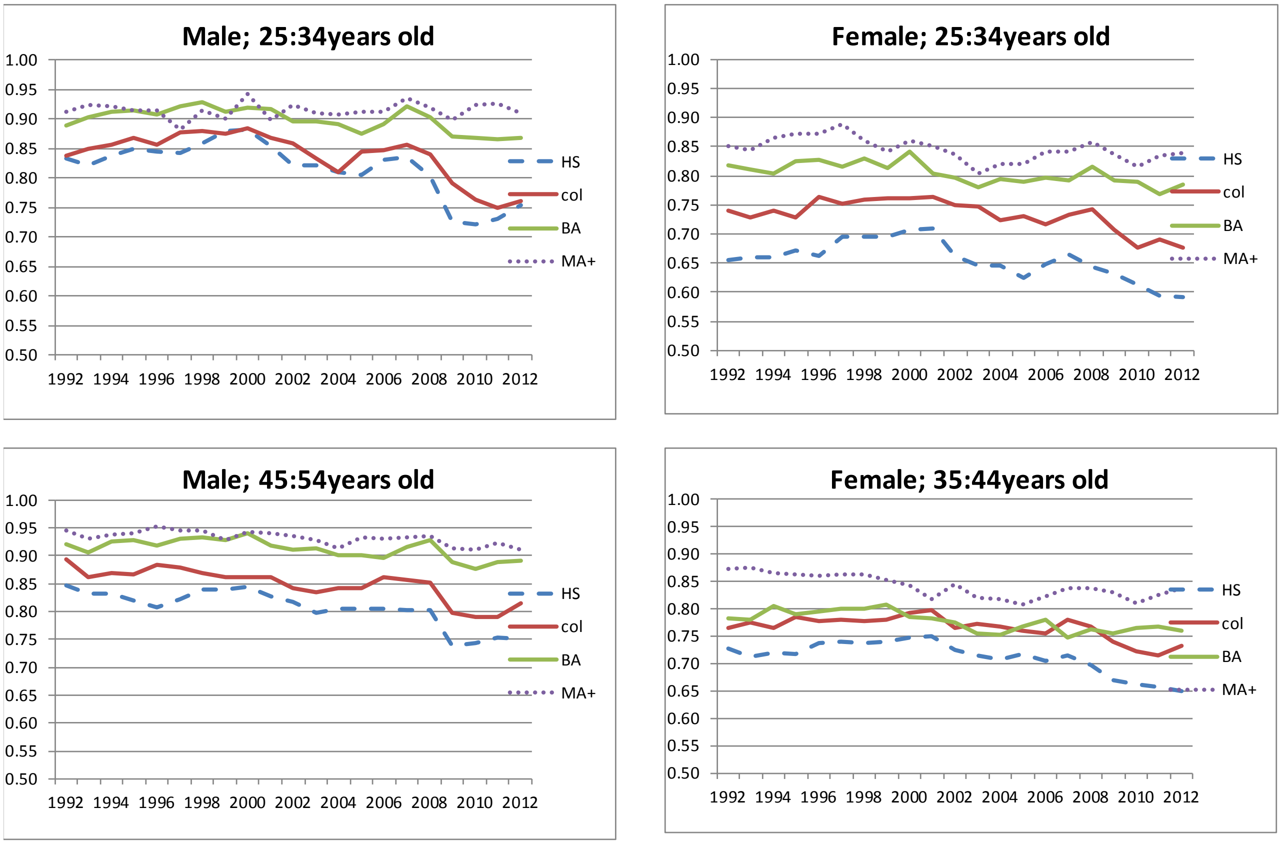


Figure 9. Compensation by education attainment (relative to those with HS diploma)

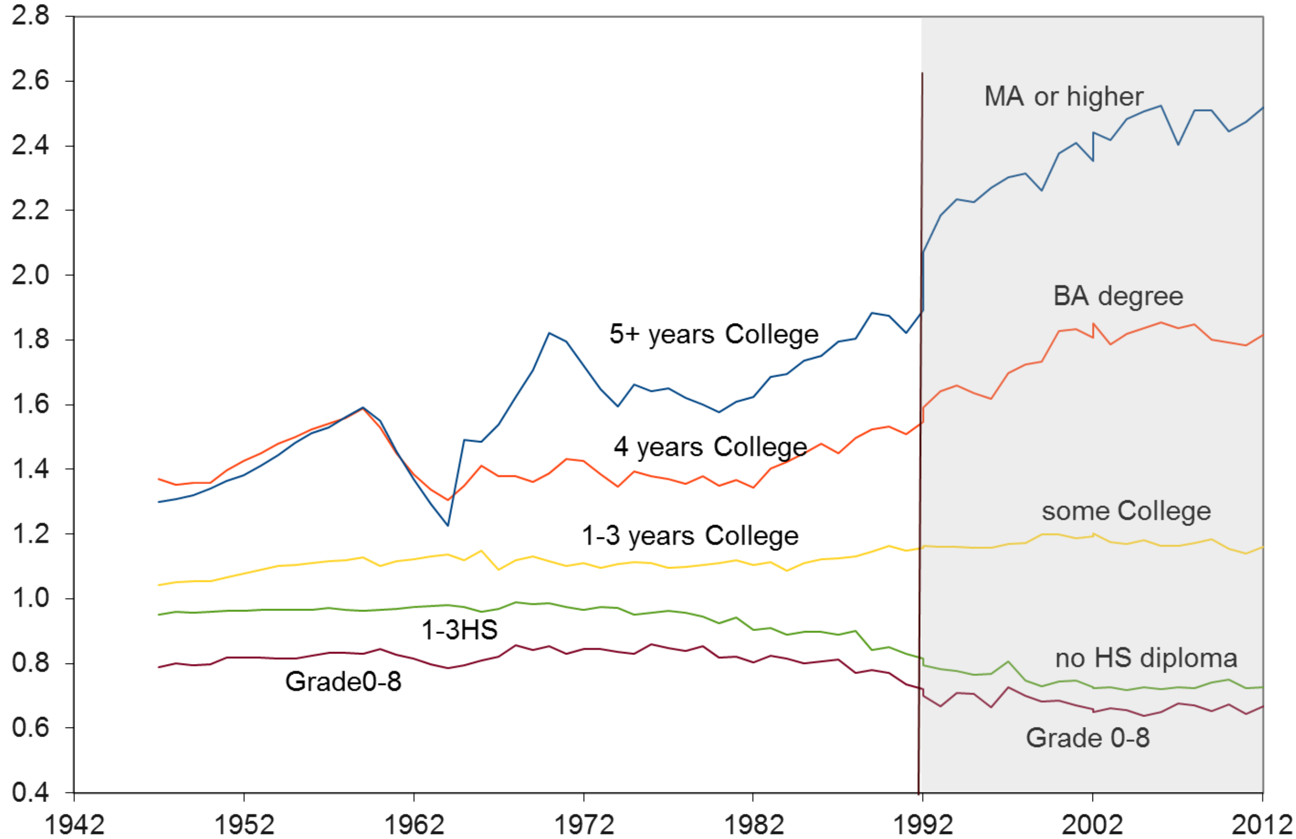


Figure 10. Compensation by age relative to 25-34 year olds

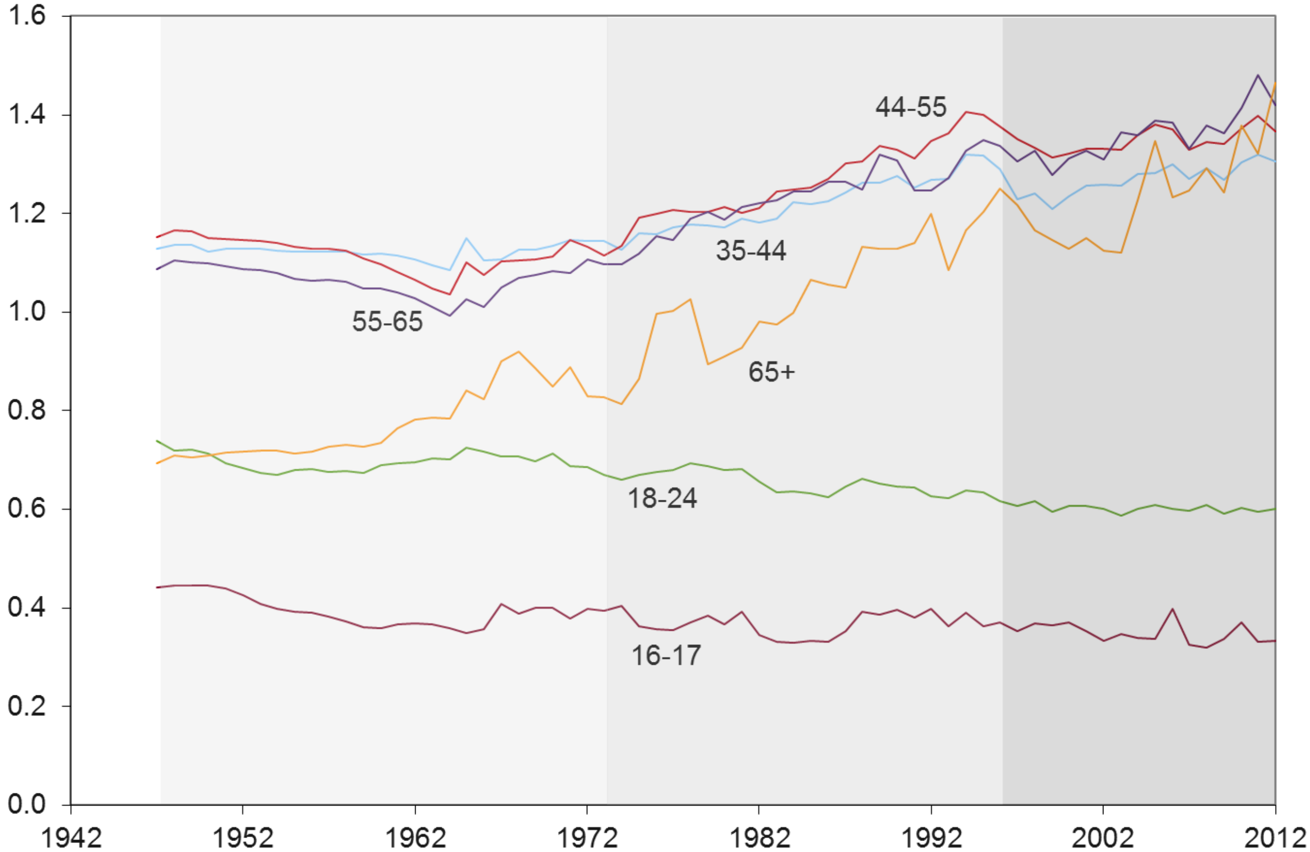


Figure 11. Contributions of Industry Groups to Value Added Growth, 1947-2012

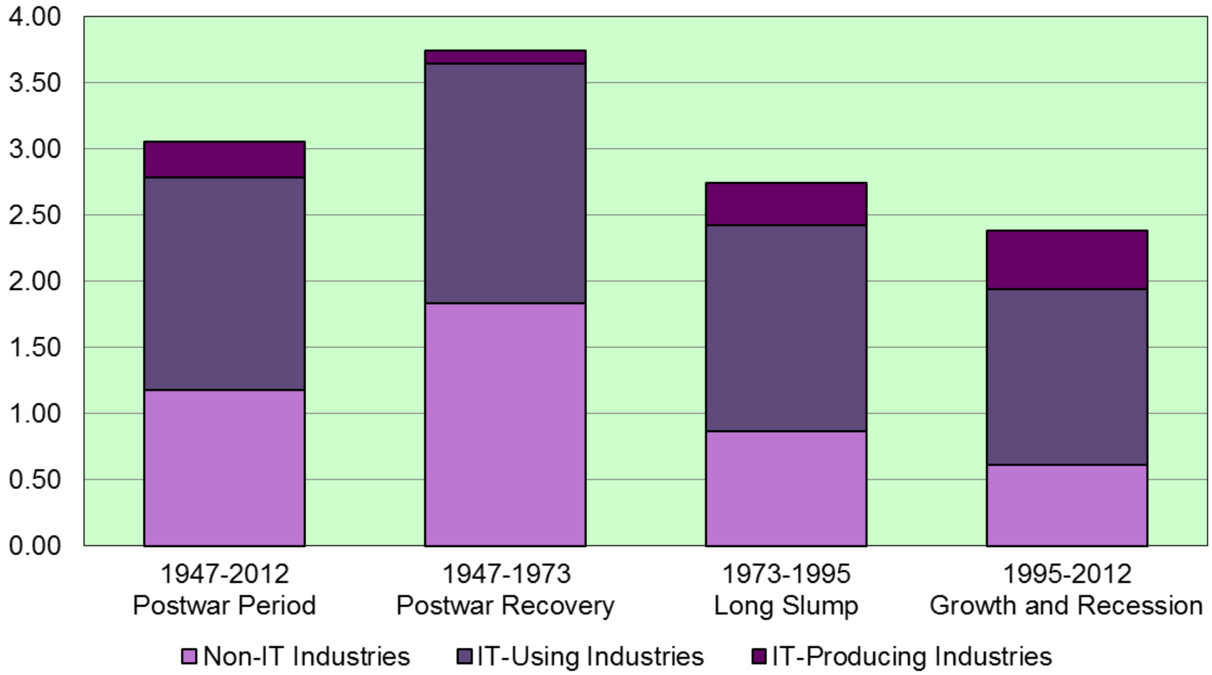


Figure 12. Contributions of Industry Groups to Value Added Growth, 1995-2012

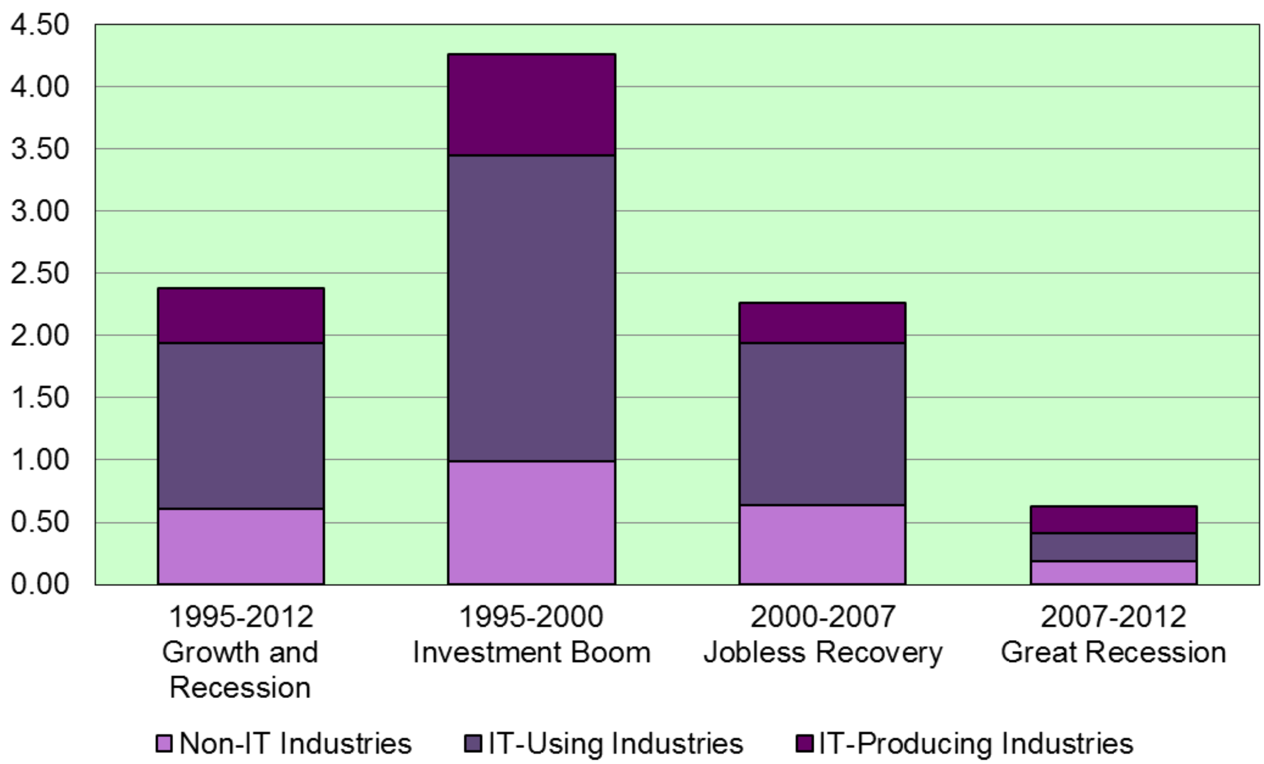


Figure 13. Industry Contributions to Value Added 1947-2012

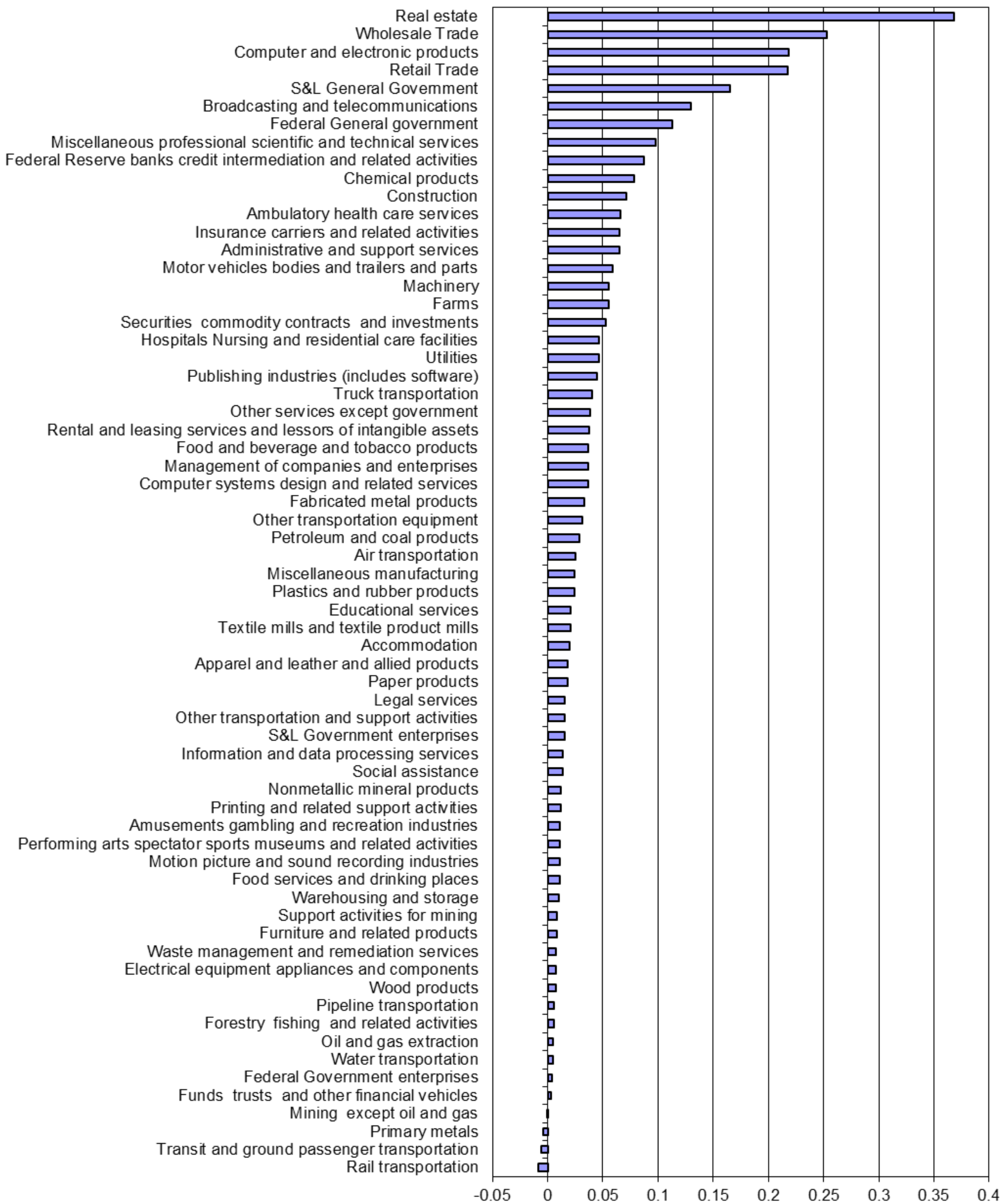


Figure 14. Contribution of Industry Groups to Productivity Growth, 1947-2012

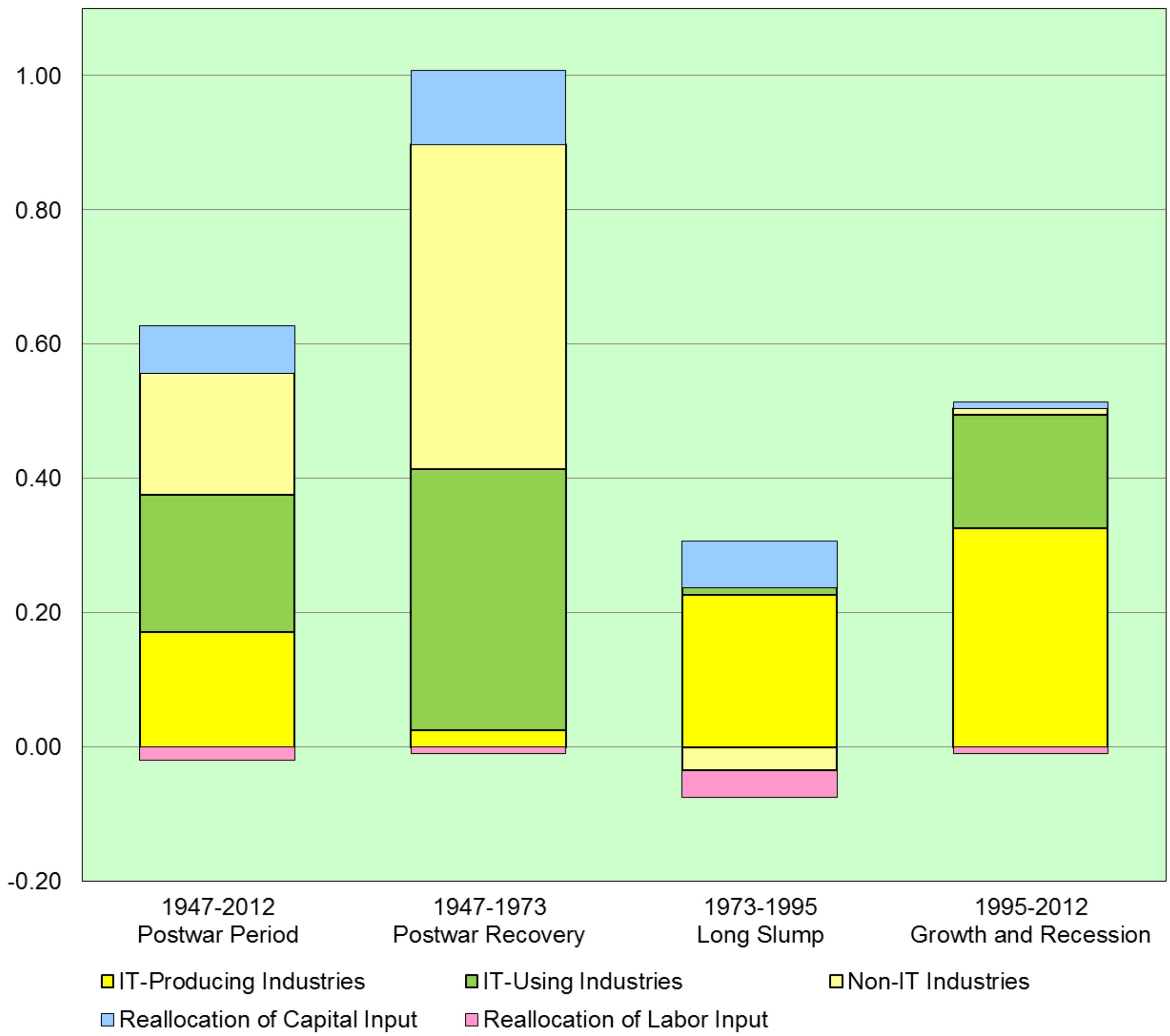


Figure 15. Contribution of Industry Groups to Productivity Growth, 1995-2012

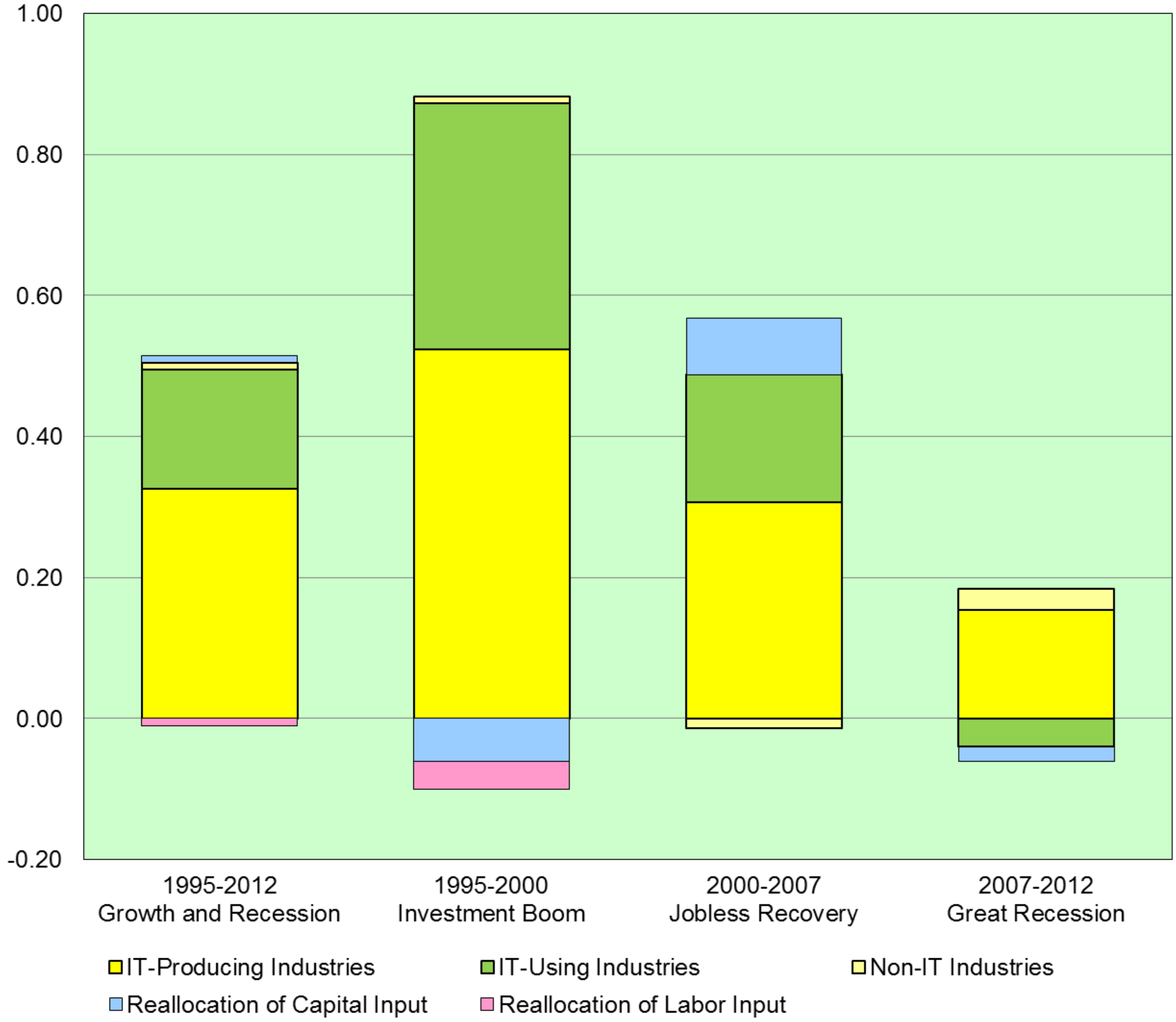


Figure 16. Industry Contributions to Productivity 1947-2012

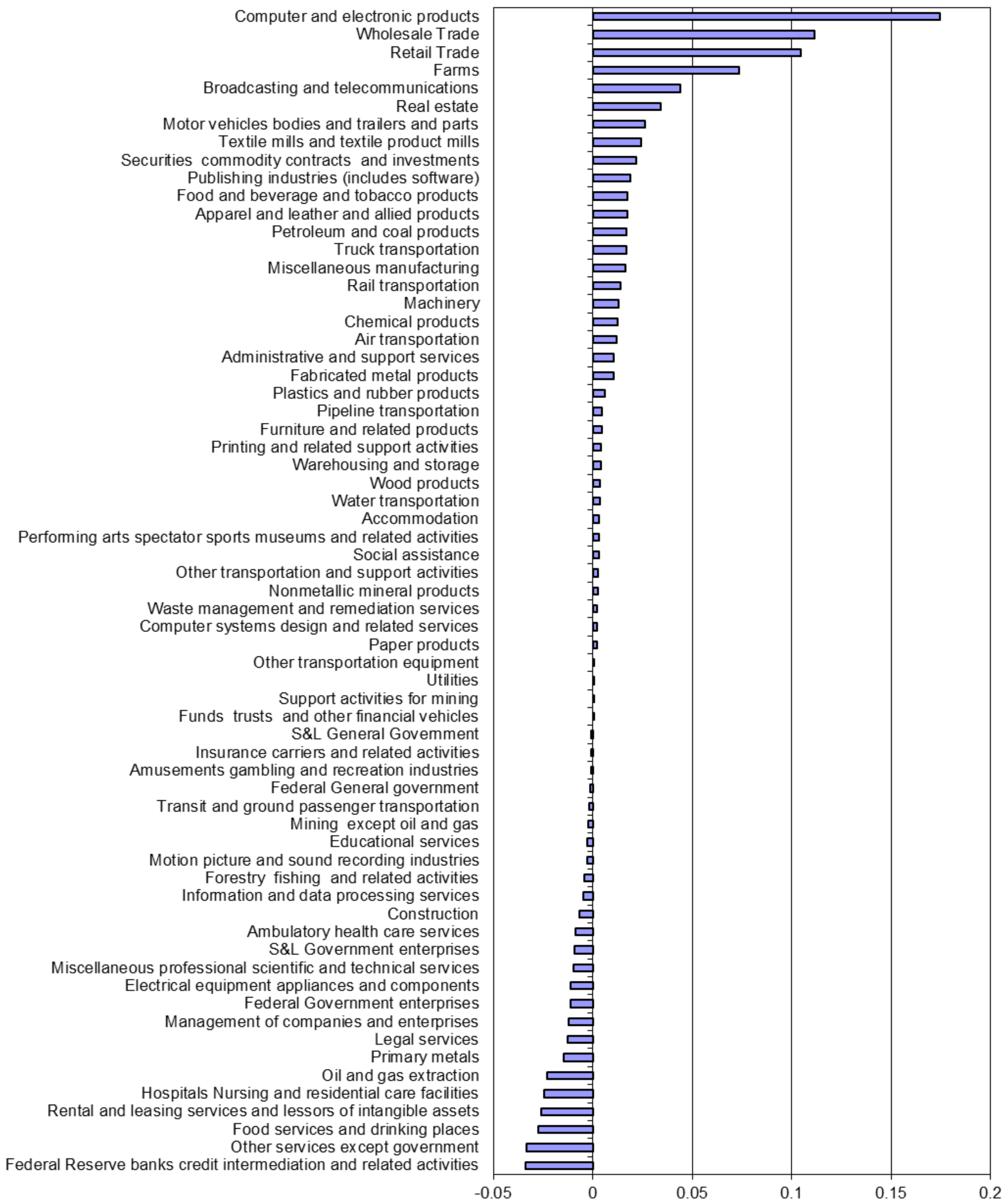


Figure 17. Sources of U.S. Economic Growth, 1947-2012

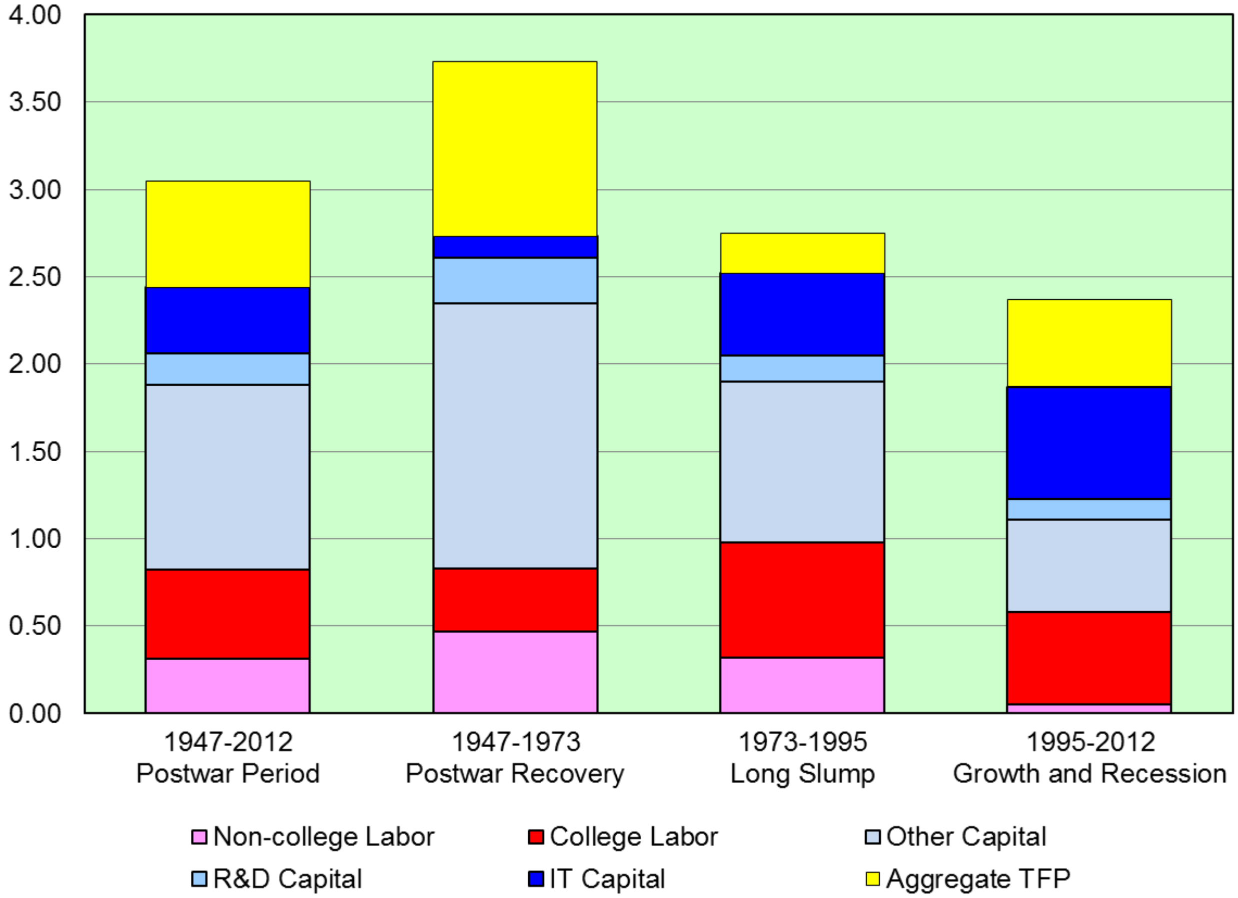


Figure 18. Sources of U.S. Economic Growth, 1995-2012

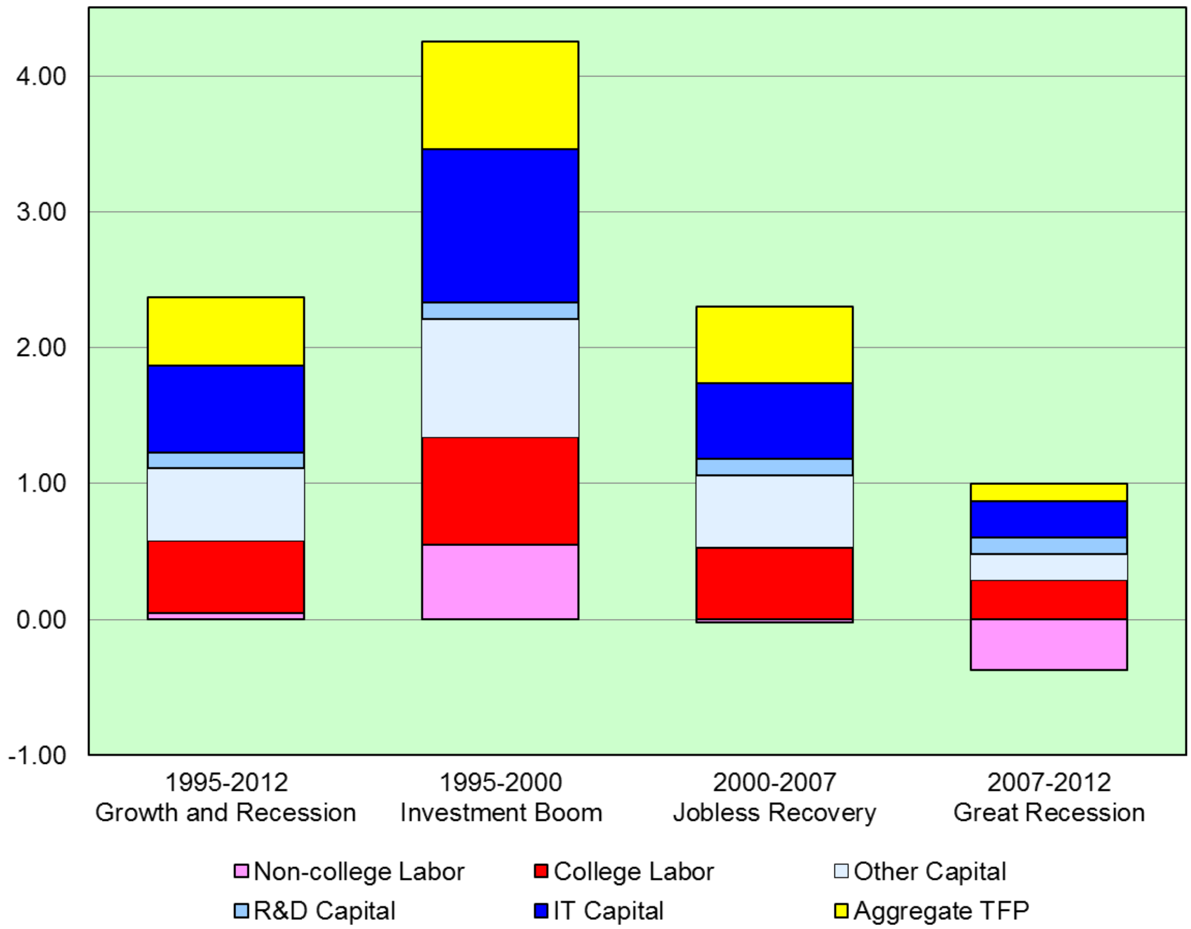


Figure 19. Contribution of Industry Groups to Productivity Growth, 2012-2022

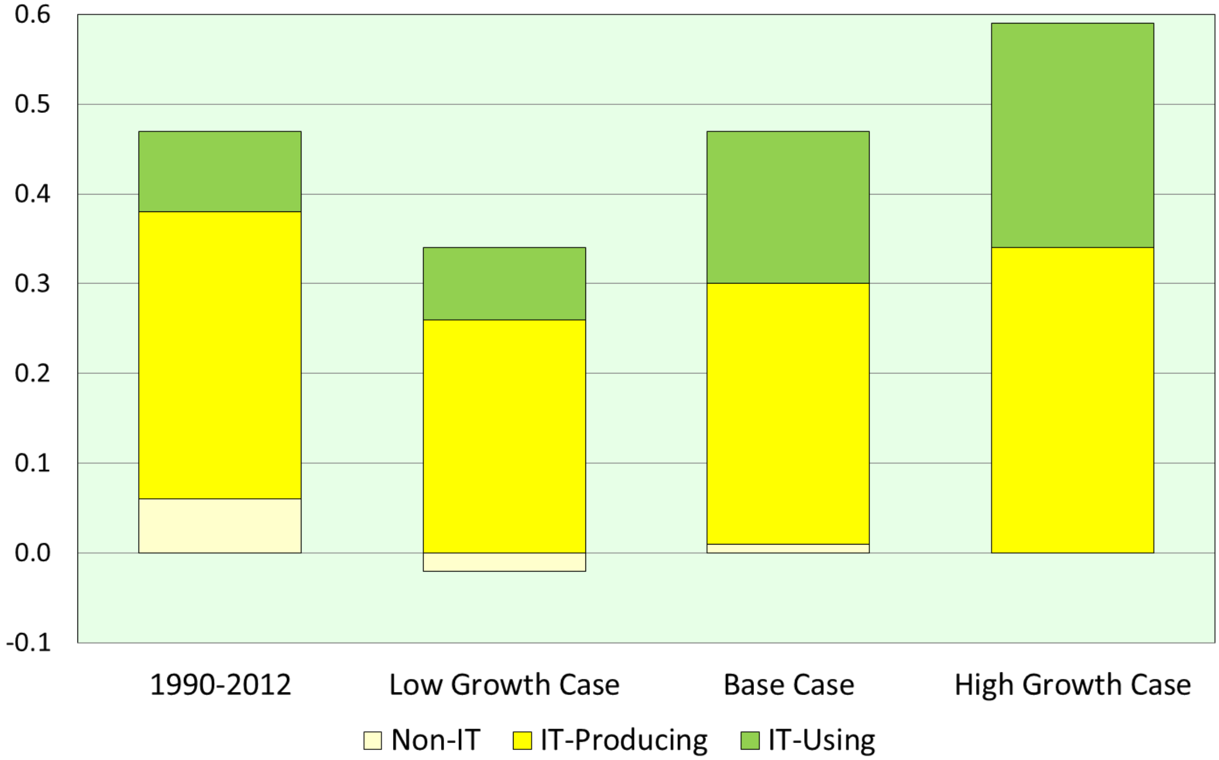


Figure 20. Range of Labor Productivity Projections, 2012-2022

Annual percentage growth rates

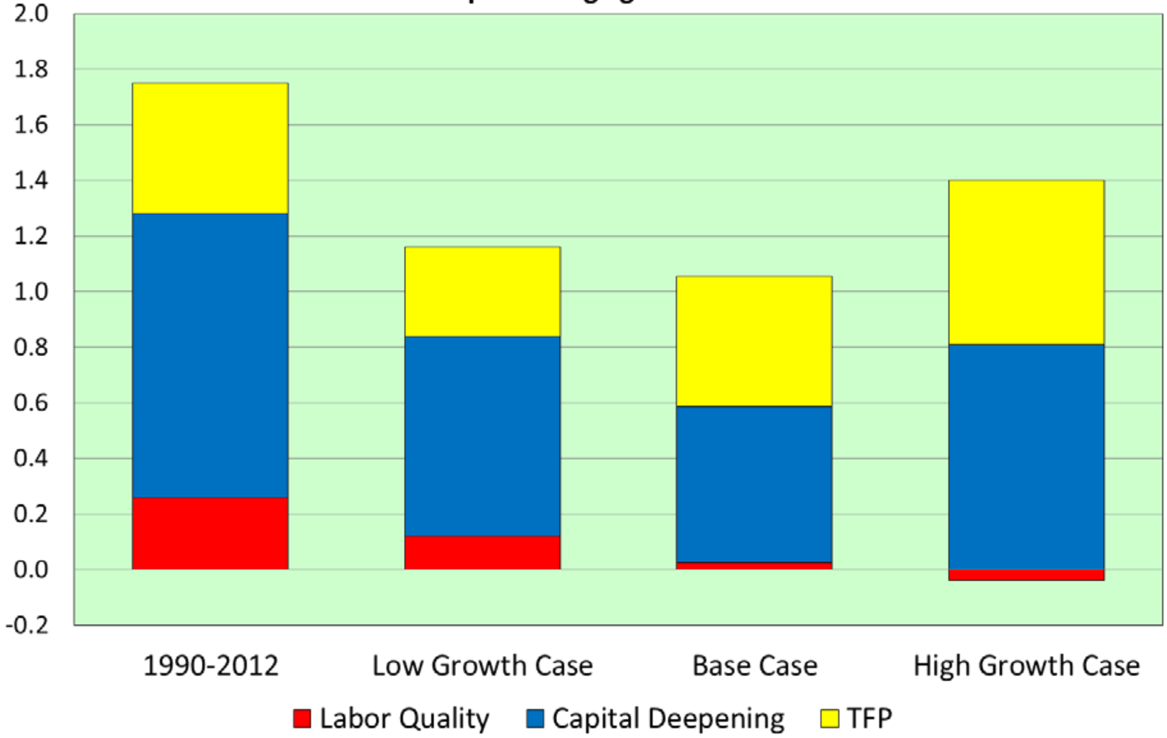


Figure 21. Range of U.S. Potential Output Projections, 2012-2022
Annual percentage growth rates