THE WORLD KLEMS INITIATIVE:

MEASURING PRODUCTIVITY AT THE INDUSTRY LEVEL

by

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1. Introduction.

The World KLEMS Initiative was established at the First World KLEMS Conference at Harvard University in August 2010[1]. The purpose of this Initiative is to generate industry-level data on outputs, inputs, and productivity. Productivity is defined as output per unit of all inputs. The inputs consist of capital (K) and labor (L), the primary factors of production, and intermediate inputs of energy (E), materials (M), and services (S). The acronym KLEMS describes these inputs. Industry-level data have been proved to be indispensable for analyzing the sources of economic growth for countries around the world.

International productivity comparisons are the second focus of industry-level productivity research. Productivity gaps between two countries are defined in terms of differences in productivity levels. These differences are measured by linking the productivity levels for each country by purchasing power parities for inputs and outputs. As an example, the purchasing power parity for Japan and the U.S. is defined as the price in Japan, expressed in yen, relative to the price

[1] For the program and participants see: http://www.worldklems.net/conference1.htm

in the U.S., expressed in dollars. Purchasing power parities can be defined in this way for commodities, industries, or aggregates like the GDP. Productivity gaps are essential for assessing competitive advantage and designing strategies for economic growth.

We review productivity measurement at the industry level in Section 2. The landmark EU (European Union) KLEMS study was completed in 2008 and provided industry-level data sets for the countries of the European Union. These data have proved to be invaluable for analyzing the slowdown in European economic growth. The EU KLEMS study also included data for Australia, Canada, Japan, Korea, and the United States. These data have been widely used for international comparisons between European countries and the leading industrialized countries of Asia and North America.

Regional organizations – LA KLEMS in Latin America and Asia KLEMS in Asia – have joined the European Union in supporting industry-level research on productivity. The Latin American affiliate of the World KLEMS Initiative, LA KLEMS, was established in 2009 at the Economic Commission for Latin American and the Caribbean (ECLAC) in Santiago, Chile. The Asian affiliate, Asia KLEMS, was founded at the Asian Development Bank Institute (ADBI) in Tokyo in 2010. The regional organizations have stimulated the development of industry-level productivity measures for the emerging economies of Asia and Latin America, such as Brazil, China, and India, as well as measures for the advanced economies of Asia, Europe, and North America.

In Section 3 we present the KLEMS framework for productivity measurement for a single country. Development of this framework within the national accounts has the important advantage that official measures can be generated at regular intervals in a standardized format.[2] The

[2] The World KLEMS website presents data sets in a common format for many of the participating countries. See: http://www.worldklems.net/data.htm

production account in current prices contains nominal outputs and incomes, while the production account in constant prices provides real outputs and inputs, as well as productivity. Paul Schreyer's (2001) *OECD Productivity Manual* provided methods for productivity measurement within the national accounts.

A key feature of the KLEMS framework is a *constant quality index of labor input* that combines hours worked for different types of labor inputs by using labor compensation per hour as weights. Similarly, a *constant quality index of capital input* deals with the heterogeneity among capital services by using rental prices of these services as weights. Schreyer's (2009) OECD Manual, *Measuring Capital,* presented methods for measuring capital services. Finally, inputs of energy, materials and services are generated from a time series of input-output tables in current and constant prices.

In 2008 the Advisory Committee on Measuring Innovation in the 21st Century to the U.S. Secretary of Commerce recommended that productivity data be incorporated into the U.S. national accounts. This was successfully completed by the Bureau of Economic Analysis (BEA), the agency responsible for the U.S. national accounts, and the Bureau of Labor Statistics (BLS), the agency that produces industry-level measures of productivity for the U.S. Susan Fleck, Steven Rosenthal, Matthew Russell, Erich Strassner, and Lisa Usher (2014) published an integrated BEA/BLS industry-level production account for the U.S. for 1998-2009 in Jorgenson, Landefeld, and Schreyer (2014).

In Section 4 we illustrate the KLEMS methodology for a single country by summarizing the industry-level productivity data for the United States for the period 1947-2012 compiled by Jorgenson, Ho, and Samuels (2016). We analyze the sources of U.S. economic growth for three broad periods: the Postwar Recovery of 1947-1973, the Big Slump of 1973-1995, following the

energy crisis of 1973, and the period of Growth and Recession, 1995-2012. To provide more detail on the period of Growth and Recession, we analyze the sources of growth for the sub-periods 1995-2000, 2000-2007, and 2007-2012 – the Investment Boom, the Jobless Recovery, and the Great Recession.

In Section 5 we introduce the KLEMS framework for international comparisons by presenting price level indices and productivity gaps. The price level index is an indicator of international competitiveness, often expressed as over- or undervaluation of currencies. A specific example is the over- or undervaluation of the Japanese yen relative to the U.S. dollar.
The price level index for Japan and the United States compares market exchange rates with purchasing power parities for the GDP.

The productivity gaps between Japan and the U.S. are indicators of the relative efficiency of two countries in transforming inputs into outputs. To measure these productivity gaps we first construct comparable measures of productivity. We then link the U.S. and Japanese outputs and inputs at the industry level by means of purchasing power parities. As an illustration, the U.S. productivity data presented in Section 4 for 1947-2012 have been linked to comparable Japanese productivity data for 1955-2012 by Jorgenson, Nomura, and Samuels (2016).

The international comparisons between Japan and the U.S. presented in Section 6 are based on industry-level purchasing power parities. These comparisons provide important information on the valuation of the Japanese yen relative to the U.S. dollar. The yen was under-valued from 1955 until the Plaza Accord of 1985. This enabled Japan to achieve a high level of international competitiveness, despite a large productivity gap with the United States. Since 1985 the yen has been over-valued, relative to the dollar, reaching a peak in 1995 that greatly undermined Japanese competitiveness. The yen finally achieved purchasing power parity with the dollar only in 2015,

restoring Japanese international competitiveness after several years of monetary policies based on quantitative easing by the Bank of Japan.

The large productivity gap between Japan and the United States that existed in 1955 gradually closed until the end of the "bubble economy" in Japanese real estate in 1991. Since that time Japanese productivity has been stagnant, while productivity in the U.S. has continued to rise. The widening productivity gap can be traced to a relatively small number of industrial sectors in Japan, mainly in trade and services, but also including agriculture. Productivity gaps for Japanese manufacturing industries have remained relatively small. This has created opportunities for formulating a Japanese growth strategy based on stimulating productivity growth in the lagging industrial sectors. Section 7 presents our conclusions.

2. **Development of World KLEMS.**

The EU (European Union) KLEMS study provided industry-level data sets on the sources of growth for the EU member countries[3]. These data have found widespread application in analyzing the slowdown in European economic growth before the financial and fiscal crisis. The initial data sets and results were presented at the EU KLEMS Conference in Groningen, The Netherlands, in June 2008[4]. Marcel P. Timmer, Robert Inklaar, Mary O'Mahony, and Bart van Ark (2010) summarized the data and analyzed the sources of economic growth in Europe in their book, *Economic Growth in Europe*.

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[3] The available data are posted on the EU KLEMS website: http://www.euklems.net/eukNACE2.shtml The EU KLEMS data set will be updated with support from the Directorate General of Economic and Financial Affairs (DG-ECFIN) of the European Commission. See: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=6&ved=0ahUKEwiTxKfch87NAhULFz4KHfHiAwMQFghCMAU&url=http%3A%2F%2Fscholar.harvard.edu%2Ffiles%2Fjorgenson%2Ffiles%2F6.2.pptx%3Fm%3D1464016998&usg=AFQjCNHJVM1YtRqOinlstZJPt6Pke5JJ5A

[4] For the program and participants see: http://www.euklems.net/conference.html

The EU KLEMS project also included data sets for Australia, Canada, Japan, Korea, and the United States. In their book, *Industrial Productivity in Europe*, Matilde Mas and Robert Stehrer (2012) presented international comparisons within Europe and between Europe and the advanced economies in Asia and North America. As European policy-makers have focused their attention on the revival of economic growth, international comparisons of the sources of growth have become essential for analyzing the impacts of changes in economic policy.

The EU KLEMS project identified Europe's failure to develop a knowledge economy as the most important explanation of the slowdown in European economic growth. Development of a knowledge economy will require investments in human capital, information technology, and intellectual property. An important policy implication is that extension of the single market to the service industries, which are particularly intensive in the use of information technology, will be essential for removing barriers to the growth of a knowledge economy in Eujroope.

The Second World KLEMS Conference was held at Harvard University on August 2012. The conference included reports on recent progress in the development of industry-level data sets, as well as extensions and applications.[5] Regional organizations in Asia and Latin America joined the European Union in supporting research on industry-level data. With growing recognition of the importance of these data, successful efforts have been made to extend the KLEMS framework to emerging and transition economies, such as Brazil, China, and India.

The Latin American affiliate 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 affiliate was coordinated by ECLAC and included seven research organizations in four leading Latin American countries – Argentina, Brazil, Chile, and

[5] The conference program and presentations are available at: http://www.worldklems.net/conference2.htm

Mexico.[6] Mario Cimoli, Andre Hofman, and Nanno Mulder (2010) summarized the results of the initial phase of the LA KLEMS project in their book, *Innovation and Economic Development*.

A detailed report on Mexico KLEMS was published in 2013 by INEGI, the National Institute of Statistics and Geography. This was presented in an international seminar at the Instituto Techologico Autonoma de Mexico (ITAM) in Mexico City on October 2013[7]. Mexico KLEMS includes industry-level productivity data for 1990-2014 that is integrated with the Mexican national accounts. This database is updated annually.[8] A very important finding is that productivity has not grown in Mexico since 1990. Periods of positive economic growth have been offset by the negative impacts of the Mexican sovereign debt crisis of 1995, the U.S. dot-com crash in 2000, and the U.S. financial and economic crisis of 2007-2009.

Asia KLEMS, the Asian affiliate of the World KLEMS Initiative, was founded in December 2010 and the first Asia KLEMS Conference was held at the Asian Development Bank Institute in Tokyo in July 2011[9]. Asia KLEMS includes the Japan Industrial Productivity database[10], the Korea Industrial Productivity database[11], and the China Industrial Productivity database[12]. Industry-level data have been assembled for Taiwan and work is underway to develop similar data for Malaysia. These databases were discussed at the Second Asia KLEMS Conference, held at the Bank of Korea in Seoul in August 2013, and the Third Asia KLEMS Conference, held at the Chung-Hua Research Institution in Taipei, Taiwan, in August 2015.[13]

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[6] Information about LA KLEMS is available on the project website: http://www.cepal.org/la-klems/noticias/paginas/9/40269/Triptico_LA_KLEMS.pdf .
[7] For the program and participants see: http://www.inegi.org.mx/eventos/2013/contabilidad_mexico/presentacion.aspx
[8] See, for example: http://www.inegi.org.mx/est/contenidos/proyectos/cn/ptf/
[9] For the program and participants see: http://asiaklems.net/conferences/conferences.asp Asia KLEMS was preceded by International Comparison of Productivity among Asian Countries (ICPAC). The results were reported by Jorgenson, Kuroda, and Motohashi (2007).
[10] http://www.rieti.go.jp/en/database/JIP2014/index.html .
[11] https://www.kpc.or.kr/eng/Productivity/kip.asp .
[12] http://www.rieti.go.jp/en/database/CIP2015/index.html .
[13] For the programs and participants see: http://asiaklems.net/conferences/conferences.asp

Kyoji Fukao (2012, 2013) has employed the Japan Industrial Productivity data base in analyzing the slowdown in productivity growth in Japan after 1991, now extending beyond the Two Lost Decades. The initial downturn followed the collapse of the “bubble” in Japanese real estate prices in 1991. A brief revival of productivity growth after 2000 ended with the sharp decline in Japanese exports in 2008-2009. This followed the rapid appreciation of the Japanese yen, relative to the U.S. dollar. When the Bank of Japan failed to respond to the adoption of a monetary policy of quantitative easing by the U.S. Federal Reserve, Japan experienced a much more severe downturn in productivity growth and a larger decline in output than the U.S.

The Third World KLEMS Conference was held in Tokyo in May 2014[14]. This conference, discussed industry-level data sets for more than 40 countries, including participants in the three regional organizations that make up the World KLEMS Initiative – EU KLEMS in Europe, LA KLEMS in Latin America, and Asia KLEMS in Asia. In addition, the conference considered research on linking data for 40 countries through the World Input-Output Database (WIOD)[15]. An important theme of the conference was the extension of the measurement of capital inputs to include intangible assets such as human capital and intellectual property.

Linked data sets are especially valuable in analyzing the development of global value chains in Asia, North America, and Europe. For this purpose international trade can be decomposed into trade by the tasks that contribute to value added at each link of the value chain. Trade in commodities involves “double-counting” of intermediate goods as products pass through the value chain. Bart Los, Timmer, and Gaaitzen J. de Vries (2015) showed that regional value chains are merging into global value chains involving all the major countries in the world.[16]

[14] http://www.worldklems.net/conference3.htm
[15] http://www.wiod.org/new_site/home.htm
[16] The World Input-Output Database will be updated through 2014 with support from the Directorate General of Economic and Financial Affairs (DG-ECFIN) of the European Commission.

The Third World KLEMS Conference included reports on new industry-level data sets for India and Russia. Russia KLEMS was developed by Timmer and Ilya Voskoboynikov (2016) and released in July 2013 by the Laboratory for Research in Inflation and Growth at the Higher School of Economics in Moscow[17]. Russia's recovery from the sharp economic downturn that followed the dissolution of the Soviet Union and the transition to a market economy has been impressive. Surprisingly, increases in productivity growth widely anticipated by observers inside and outside Russia have characterized only the service industries, which were underdeveloped under central planning. Mining industries have attracted large investments, but these have not been accompanied by gains in efficiency. The collapse in world oil prices poses an important challenge for the future growth of the Russian economy.

The India KLEMS database was released in July 2014 by the Reserve Bank of India[18], shortly after the Third World KLEMS Conference in Tokyo. This database covers 26 industries for the period 1980-2011. Beginning in the 1980's liberalization of the Indian economy resulted in a gradual and sustained acceleration in economic growth. The most surprising feature of this acceleration has been the stagnant share of manufacturing and the rapid growth in the share of services. Given the shrinking share of agriculture and the size of the Indian agricultural labor force, another surprise is that growth of capital input has been the most important source of growth in manufacturing and services, as well as more recently in agriculture.

See: http://scholar.harvard.edu/files/jorgenson/files/6.4_timmer_gvcs2.pdf

[17] See: http://www.hse.ru/en/org/hse/expert/lipier/ruklems

[18] https://rbidocs.rbi.org.in/rdocs/PublicationReport/Pdfs/EPGIKLEMS110614.pdf Details about the Research Team and the preparation of the Report are presented in the Foreward, pp. A-C.

3. The KLEMS Framework for Productivity Measurement.

Jorgenson, Frank M. Gollop, and Barbara M. Fraumeni (1987) constructed the first data set containing annual time series data on outputs, inputs of capital, labor, and intermediate goods, and productivity for all the industries in the U.S. economy. This study provided the model for the methods of economy-wide and industry-level productivity measurement presented in Schreyer's (2001) OECD Manual, *Measuring Productivity*. The hallmarks of these methods are constant quality indices of capital and labor services at the industry level and indices of energy, materials, and services inputs constructed from a time series of input-output tables.

Jorgenson, Mun S. Ho, and Kevin J. Stiroh (2005) updated the U.S. data set and revised it to include investment in information technology (IT). This required new data on the production of hardware, telecommunications equipment, and software, as well as inputs of IT capital services. The new data set has demonstrated the importance of industry-level productivity growth in understanding the U.S. Investment Boom of the 1990s. Jorgenson, Ho, and Stiroh (2005) provided the framework for the new data and for the international comparisons of Europe, Japan, and the U.S. presented by Jorgenson (2009).

The key idea underlying a *constant quality index of labor input* is to capture the heterogeneity of different types of labor inputs in measuring the quantity of labor input. Hours worked for each type of labor input are combined into a constant quality index of labor input, using labor compensation per hour as weights. Constant quality indices of labor input for the United States at the industry level are discussed in detail by Jorgenson, Ho, and Stiroh (2005, Chapter 6, pp. 201-290).

Similarly, a *constant quality index of capital input* deals with the heterogeneity among different types of capital inputs. These capital inputs are combined into a constant quality index,

using rental prices of the inputs as weights, rather than the asset prices used in measuring capital stocks. This makes it possible to incorporate differences among asset-specific inflation rates that are particularly important in analyzing the impact of investments in information technology, as well as differences in depreciation rates and tax treatments for different assets. Constant quality indices of capital input for the United States at the industry level are presented by Jorgenson, Ho, and Stiroh (2005, Chapter 5, pp. 147-200).

The KLEMS framework for productivity measurement incorporates a time series of input-output tables in current and constant prices. Estimates of intermediate inputs of energy, materials, and services are generated from these tables. Details on the construction of the time series of input-output tables and estimates of intermediate inputs are presented by Jorgenson, Ho, and Stiroh (2005, Chapter 4, pp. 87-146).

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

In Chapter 20 of the United Nations (2009) *System of National Accounts 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 prototype system of U.S. national accounts presented by Jorgenson and Landefeld (2006) is consistent with the OECD Manual, *Measuring Productivity*, the United Nations *System of National Accounts 2008*, and the OECD Manual, *Measuring Capital*.

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[19]:

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

In response to the Advisory Committee's recommendations, BEA and BLS 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).[20] This is a critical step in implementing the new architecture. The omission of productivity statistics from the NIPAs and *SNA 1993* has been a serious barrier to analyzing the sources of economic growth.

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[19] 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 Jorgenson. The Advisory Committee met on February 22 and September 12, 2007, to discuss its recommendations. The final report was released on January 18, 2008.

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

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.

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).

BEA's annual input-output data were employed in the industry-level production accounts presented by Susan Fleck, Rosenthal, Matthew Russell, Strassner, and Lisa Usher (2014) in their paper for the Second World KLEMS Conference, "A Prototype BEA/BLS Industry-Level Production Account for the United States." The paper covers the period 1998-2009 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. This paper was published in a second volume on the new architecture for the U.S. national accounts, edited by Jorgenson, Landefeld, and Schreyer (2014).

Stefanie H. McCulla, Alyssa E. Holdren, and Shelly Smith (2013) have summarized 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.

The 2014 benchmark revision of the U.S. industry accounts is incorporated into the paper by Rosenthal, Matthew Russell, Samuels, Strassner, and Lisa Usher (2015), "Integrated Industry-Level Production Account for the United States: Intellectual Property Products and the 2007 NAICS." The paper covers the period 1997-2012 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.[21] This paper was presented at the Third World KLEMS Conference and will be published in a volume edited by Jorgenson, Fukao, and Timmer (2016).

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

Jorgenson and Schreyer (2013) have shown how to integrate a complete system of production accounts at the industry level into the United Nations *System of National Accounts 2008.* To illustrate the application of these accounts, we summarize the industry-level production account for the United States for 1947-2012 presented by Jorgenson, Ho, and Samuels (2016) at the Third World KLEMS Conference. This will be published in the volume edited by Jorgenson,

[21] For current data, see: http://www.bea.gov/industry/index.htm .

Fukao, and Timmer (2016). The lengthy time series is especially valuable in comparing recent changes in the sources of economic growth with longer-term trends.

The NAICS industry classification includes the industries identified by Jorgenson, Ho, and Samuels (2016) 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 (2016) 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. All other industries are classified as Non-IT.

Value added in the IT-producing industries during 1947-2012 is only 2.5 percent of the U.S. economy. Value added in the IT-using industries is about 47.5 percent and the remaining fifty percent is in the Non-IT industries. 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 1 shows 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 remained relatively constant through 1995. Figure 2 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. The contribution of the Non-IT industries also declined substantially. Figure 3 gives the contributions to value added for the 65 individual industries over the period 1947-2012.

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 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 aggregate productivity growth rate 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 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 1947-2012. 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 this Postwar Recovery, but became the predominant source of growth during the Long Slump, 1973-1995, and increased considerably during the period of Growth and Recession of 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 1995-2012 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, 2000-2007, and 2007-2012 – 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 period of Jobless Growth, but dropped to nearly zero 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 became substantially negative during the Great Recession. The contributions of reallocations of capital and labor inputs were not markedly different from historical averages.

Figure 6 gives the contributions of each of the 65 industries to productivity growth for the period 1947-2012. 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 growth. 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 price of an asset is transformed into the price of 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 high rates of depreciation – imply that cost of capital for 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 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.

All the sources of economic growth contributed to the U.S. growth resurgence during the 1995-2000 Investment Boom represented in Figure 8, relative to the Long Slump of 1973-1995 in Figure 7. Jorgenson, Ho, and Stiroh (2005) have analyzed the sources of the U.S. growth resurgence in greater detail. After the dot-com crash in 2000 the overall growth rate of the U.S. economy dropped to well below the long-term average of 1947-2012. The contribution of investment also declined below the long-term average, but the shift from Non-IT to IT capital input continued. Jorgenson, Ho, and Stiroh (2008) argue that the rapid pace of U.S. economic growth after 1995 was not sustainable.

The contribution of labor input dropped precipitously during the period of Growth and Recession, accounting for most of the decline in U.S. 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 substantially to U.S. economic growth during the Great Recession period after 2007. 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. These trends represent increased rates of substitution of capital for labor and college-educated workers for non-college workers.

5. The KLEMS Framework for International Comparisons.

We introduce the framework for international comparisons with a brief discussion of the two basic concepts, the price level index and the productivity gap. The price level index is defined as the ratio of the purchasing power parity to the market exchange rate. Purchasing power parity represents the price of a commodity in Japan, expressed in yen, relative to the price in the U.S., expressed in dollars. By comparing this relative price with the market exchange rate of the yen and the dollar, we obtain the price barrier faced by Japanese producers in competing with their American counterparts in international markets.

As a specific illustration, the purchasing power parity of a unit of the Gross Domestic Product (GDP) in Japan and the U.S. in 2005 was 124.9 yen per dollar, while the market exchange rate was 110.2 yen per dollar. The price level index was 1.13, so that the yen was over-valued relative to the dollar by thirteen percent. Firms located in Japan had to overcome a thirteen percent price

disadvantage in international markets to compete with U.S. producers. This provides a quantitative measure of the international competitiveness of Japan and the U.S. in 2005.

Jorgenson, Nomura, and Samuels (2016) give estimates of price level indices for 36 industries in Japan and the U.S. These estimates are derived from detailed purchasing power parities for 174 products, constructed within the framework of a bilateral Japan-US input-output table for 2005 by Nomura and Miyagawa (2015). Jorgenson, Nomura, and Samuels (2016) develop price level indices for capital stock and capital services for 33 types of capital assets, including research and development, land, and inventories. Finally, they develop price level indices for 1680 categories of labor inputs, cross-classified by gender (2), age (6), education attainment (4), and industry (35) categories. The detailed price level indices are used to construct prices for outputs and the KLEMS inputs of the 36 industries – capital (K), labor (L), energy (E), materials (M), and services (S).

Price level indices between Japan and the U.S. have real counterparts in the productivity gaps between the two countries. At the economy-wide level total factor productivity (TFP) is defined as the GDP divided by the total of capital and labor inputs. This can be distinguished from labor productivity, the ratio of GDP to labor input, or capital productivity, the ratio of GDP to capital input. The productivity gap reflects the difference between the levels of TFP and captures the relative efficiency of production in the two countries.

We trace the Japan-US productivity gap to its sources at the industry level by comparing industry-level production accounts for Japan and the U.S. that employ similar national accounting concepts. The U.S. production account presented in Section 4 was developed by Jorgenson, Ho, and Samuels (2016), who extended the estimates of Jorgenson, Ho, and Stiroh (2005) backward to 1947 and forward to 2012. Jorgenson, Nomura, and Samuels (2016) extended the Japanese

production account presented by Jorgenson and Nomura (2007) backward to 1955 and forward to 2012.

The convergence of Japanese economy to U.S. levels of productivity has been analyzed in a number of earlier studies – Jorgenson, Kuroda, and Nishimizu (1987), Jorgenson and Kuroda (1990), van Ark and Pilat (1993), Kuroda and Nomura (1999), Nomura (2004), and Cameron (2005), as well as Jorgenson and Nomura (2007). The productivity gap between Japan and the U.S. is defined as the difference between unity and the ratio of levels of total factor productivity in the two countries. For example, in 1955, three years after Japan regained sovereignty at the end of the Allied occupation in 1952, Japan's TFP was 45.4 percent of the U.S. level, so that the productivity gap between the two economies was 54.6 percent.

Japanese GDP grew at double-digit rates for a decade and a half, beginning in 1955. This rapid growth is often associated with the "income-doubling" plan of Prime Minister Hayato Ikeda. Ikeda took office in 1960 and immediately announced a plan to double Japanese incomes during the decade 1960–1970. The growth rate of Japanese GDP averaged more than ten percent per year from 1955–1970, considerably more than income-doubling growth rate of seven percent. The growth of TFP contributed about 40 percent of this growth in output, while growth of capital and labor inputs contributed around 60 percent.

The oil price shock of 1973 slowed Japanese growth, but Japanese GDP doubled more than three times between 1955 and 1991. The growth of TFP accounted for a little under a third of this, while growth of capital and labor inputs accounted for slightly more than two-thirds. U.S. economic growth averaged less than half the Japanese growth rate from 1955–1991. Japanese TFP grew at 2.46 percent per year until 1991, while annual U.S. TFP growth averaged only 0.46

percent. In 1991 Japanese TFP reached 92.9 percent of the U.S. level, leaving a productivity gap of 7.1 percent.

The collapse in Japanese real estate prices ended the "bubble economy" in 1991 and ushered in a period of much slower growth, often called the Lost Decade. The Japanese growth rate plummeted to only 0.70 percent per year from 1991–2012, less than a tenth of the growth rate from 1955–1991. U.S. economic growth continued at 2.71 percent during 1991–2012, including the information technology investment boom of 1995–2000, when the growth rate rose to 4.40 percent per year. After 1991 Japanese TFP was almost unchanged, falling at 0.05 percent per year, while U.S. TFP continued to grow at 0.53 percent. By 2012 Japan-U.S. productivity gap had widened to 17.3 percent, the level of the early 1980's.

Hamada and Okada (2009) have employed price level indices to analyze the monetary and international factors behind Japan's Lost Decade. The Lost Decade is discussed in much greater detail by Hamada, Kashyap, and Weinstein (2010), Iwata (2011), and Fukao (2013). The Lost Decade of the 1990s in Japan was followed by a brief revival in economic growth. The Great Recession of 2007–2009 in the U.S. was transmitted to Japan by a sharp appreciation of the yen in response to quantitative easing by the Federal Reserve. This led to a downturn in Japan that was more severe than in any of the other major industrialized countries, providing the setting for a renewed focus on economic growth by the government of Prime Minister Shinzo Abe in 2012 under the rubric of Abenomics.

6. Industry-Level Production Accounts for Japan and the U.S.

We estimate purchasing power parities (PPP) for gross domestic product (GDP) in Japan and the U.S. in 2005 from industry-level PPPs for gross output, factor inputs of capital and labor, and

intermediate inputs of energy, materials, and services. The PPP for GDP is an index of the industry-level PPPs for value added, weighted by average industry shares of value added in the two countries. Similarly, the PPPs for factor inputs and intermediate inputs by industry are defined as indices of PPPs for these inputs at the elementary level, using average industry shares as weights. Taking estimates of the PPPs for 2005 as a benchmark, we derive time-series estimates of the PPPs by extending the benchmark back to 1955 and forward to 2012, using time-series data on prices for outputs and inputs.

Table 1 presents our estimates of PPPs and price level indices (PLIs) for Japan relative to the U.S. Figure 9 represents the long-term trends of PPPs for output and inputs.[22] The yen-dollar exchange rate is represented as a shadow in Figure 9. If the PPP is higher than the exchange rate, the Japanese price is higher than the U.S. price. Through the mid-1970s the Japanese price for output (GDP) was lower than the U.S. price. The Japanese prices of inputs of capital, labor, energy, materials and services (KLEMS), except for energy, were lower than the U.S. prices as well.

Lower input prices, especially the price of labor input (only 17 percent of the U.S. level in 1955), provided a source of international competitiveness for Japanese products from the 1950s until the middle of 1970s. During this period the PPP for materials was quite stable and the rise of the PPP for services was nearly proportional to the rise in the PPP for output. The PPPs for capital and labor inputs increased much more rapidly than the PPP for output. With the rise in the price of labor and the yen appreciation in the 1970s, Japan's competitiveness in international markets eroded substantially.

By 1985 the yen was undervalued by 13 percent, based on our estimate of the price level index (PLI) for GDP. After the Plaza Accord of 1985 the rapid strengthening of the yen reversed

[22] Our estimates of PPP for GDP are based on outputs, while the Eurostat-OECD PPPs presented in Table 1 are based on expenditures. Although the two PPP estimates are nearly identical in 2012, our output-based estimates are higher through the beginning of the 1970s and lower in the 1990s and 2000s.

this relationship, leading to an overvaluation of the yen by 28 percent in 1990. The revaluation of the yen continued through 1995, leading to a huge overvaluation of 75 percent. At that time the price of labor input was 54 percent higher in Japan, which posed a formidable barrier to Japanese products in international markets.

Japanese policy makers required more than a decade to deal with the overvaluation of the yen that followed the Plaza Accord. This was accomplished through domestic deflation, with a modest devaluation of the yen. The PLI for GDP in Japan, relative to the U.S., declined by 4.64 percent annually through 2007 from the peak attained in 1995. The decline in the PPP for GDP of 2.77 percent per year was the result of modest inflation in the US of 1.92 percent and deflation in Japan of 0.85 percent. In addition, the yen-dollar exchange rate depreciated by 1.87 percent per year.

Although the market exchange rate of the yen approached the PPP for GDP in 2007, the yen appreciated sharply due to quantitative easing by the Federal Reserve in response to the financial crisis in the U.S. In November 2011 the market exchange rate reached 75.5 yen per dollar, the highest level since World War II. By 2012 the price level index for GDP was 34.5 percent higher in Japan. In response to quantitative easing by the Bank of Japan, the yen sharply declined, reaching 119.6 yen per dollar as of the end of February 2015. This is well below the estimate of the PPP for GDP of 107.3 in 2012 and restored Japanese international competitiveness.

Figure 10 gives the contribution of individual industries to the price level index for GDP. For example, the Japanese Wholesale and Retail industry has the largest contribution to the PLI for GDP. By contrast, Japan’s Medical Care sector in services and Motor Vehicles and Primary Metal sectors in manufacturing contributed negatively to the PLI for GDP. All three of these industries are highly competitive with their U.S. counterparts.

Table 2 summarizes the productivity gaps between Japan and the U.S. This table compares output, output per capita, input per capita, and total factor productivity (TFP) for the two countries over the period 1955–2012. Differences in output per capita can be decomposed into differences in input per capita and differences in TFP. For example, Japanese GDP was 26.3 percent of the U.S. level in 2012. GDP per capita in Japan was 64.6 percent of the U.S. level, while Japanese input per capita was 78.1 percent and Japanese TFP was 82.7 percent.

Differences in input per capita in Table 2 result from differences in capital and labor inputs. In 1955 Japanese labor input per capita was 60.6 percent of the U.S. level in 1955. The gap of 39.4 percent was the result of the lower quality of labor in Japan, reaching only 57.6 percent of the U.S. level. After 1970 the lower quality of Japanese labor was largely offset by longer hours worked per capita, 39.1 percent longer in 1970. Subsequently, Japan reduced hours worked per capita and improved labor quality, reducing the gap in labor quality to around 10.0 percent in 2010.[23]

The level of Japanese capital input per capita remains significantly below the U.S. level, presenting a striking contrast to labor input. In 1955 Japanese capital input per capita was only 17.3 percent of the U.S. level, but rapidly rising levels of investment in Japan reduced the gap to 46.3 percent by 1973. The gap continued to close and Japanese capital input per capita reached 79.4 percent of the U.S. level in 1995. The U.S. investment boom of the late 1990s widened the gap to 29.1 percent in 2000 and 36.3 percent in 2012, while an investment slump in Japan followed the collapse of the bubble economy.

The estimates of input per capita by Jorgenson and Nomura (2007) have been revised downward by Jorgenson, Nomura, and Samuels (2016) and productivity gaps have been revised

[23] By comparison with Jorgenson and Nomura (2007), the PPPs for labor were revised upward, reflecting the shift of the base year from 1990 to 2005 and the revision of Japanese data. Nomura and Shirane (2014) treat full-time, part-time, and temporary employees separately. The PPP for labor was revised upward from 105.0 to 114.1 yen per dollar in 2000. This revision reduced the volume and quality level indices for labor, although the volume level index for hours worked was not affected. The downward revision in the volume of labor increased the level index for TFP.

upward. The Japan-U.S. gap for total factor productivity (TFP) in 1955 was 54.6 percent. This gradually declined over the following 36 years and reached a low of 7.1 percent in 1991, as shown in Figure 11. Table 3 presents the sources of economic growth in Japan and the U.S. for 1955-2012. The growth rate of TFP in Japan was 2.46 percent per year from 1955 to 1991, but became slightly negative after 1991, averaging -0.05. By comparison the growth rate of TFP in the U.S. was 0.46 per year from 1955–1991 and 0.53 percent after 1991.

Figure 12 presents Japan-U.S. gaps in total factor productivity (TFP) in manufacturing and non-manufacturing sectors for the period 1955–2012. In 1955 both gaps were very large. The TFP gap for manufacturing disappeared by 1980[24] and the overall TFP gap reflected the lower TFP in non-manufacturing. Japanese manufacturing productivity relative to the U.S. peaked at 103.8 in 1991 and deteriorated afterward, leaving a current gap that is almost negligible. The gap for non-manufacturing also contracted from 1955 to 1991, when the gap reached 8.9 percent, but expanded until the end of the period in 2012.

Figure 13 presents the contributions of each industry to the overall TFP gap for the two countries. Industries are ordered by their contributions to the TFP gap. The contribution of each industry to the aggregate TFP gap uses the Domar weights we have described in Section 4. Note that TFP gaps for Public Administration and Household sectors are zero by definition, since the outputs of these industries consist entirely of total inputs.

In 2005, Japanese productivity exceeded that in the U.S. for 12 of 36 industries, led by Medical Care. This industry made a contribution to Japanese TFP, relative to the U.S., of 4.1 percentage points. This reflects the higher output price of medical care services in the U.S. shown

[24] Cameron (2005) analyzes the convergence of Japan's manufacturing productivity to the U.S. level and estimates the difference in TFP between Japan and the United States in 1989 as 91.3. Our estimate is 102.2 in the same year. The main source the difference is that he used the PPP estimates from Jorgenson and Nomura (2007). Our new estimates are revised upward considerably relative to Jorgenson and Nomura (2007).

10. Other domestically oriented industries in Japan, such as Wholesale and Retail Trade, Other Services, Finance and Insurance, Construction, Electricity and Gas, and Real Estate, have much lower productivity levels than their U.S. counterparts and made negative contributions of 16.7 percent to the overall TFP gap in 2005.

The productivity level of Agriculture, Forestry, and Fishery industry is only a little more than half the level of its U.S. counterpart. Not all of this gap can be traced to differences in the small scale of Japanese farms or differences in the fertility of land between the two countries. One of the targets for the growth strategy proposed by the Abe Administration is to reform Japanese agricultural cooperatives. These organizations contribute substantially to the higher costs of Japanese agricultural products and the lower productivity of Japanese agriculture.

7. Conclusions

We conclude that industry-level data sets on productivity and economic growth have been very valuable in analyzing the sources of economic growth for countries in Asia, Europe, and North and South America. Beginning with the EU KLEMS study completed in 2008, industry-level data sets have been compiled for more than forty countries. These include the advanced economies of the European Union, as well as Australia, Canada, Korea, Japan, and the United States.

The Latin American regional affiliate of the World KLEMS Initiative, LA KLEMS, has generated data sets for the emerging economies of Argentina, Brazil, Chile, and Mexico. The Asian affiliate, Asia KLEMS, includes data sets for the China and India, the two largest of the world’s emerging economies, as well as Japan, Korea, and Taiwan. Finally, an industry-level data set has been constructed for Russia at the Higher School of Economics in Moscow.

Industry-level production accounts are now prepared on a regular basis by national statistical agencies in Australia, Canada, Denmark, Finland, Italy, Mexico, The Netherlands, Sweden, and the United Kingdom, as well as the United States.[25] These accounts provide current information about the growth of outputs, inputs, and productivity at the industry level and can be used in international comparisons of patterns of structural change like those presented by Jorgenson and Timmer (2011). The World KLEMS Initiative has made it possible to extend these comparisons to countries around the world, including important emerging and transition economies.

The KLEMS framework for productivity measurement is employed in analyzing the sources of growth of the United States in Section 3 and making international comparisons between the U.S. and Japan in Section 5. Industry-level data for the United States shows that replication of established technologies explains by far the largest proportion of U.S. economic growth. Replication takes place through the augmentation of the labor force and the accumulation of capital. International productivity comparisons reveal similar patterns for the world economy, its major regions, and leading industrialized, developing, and emerging economies.[26] Studies are now underway to extend these comparisons to the countries included in the World KLEMS Initiative.

Innovation is defined as the growth in output that is not explained by the growth of input. In the KLEMS framework this is measured by productivity growth. Innovation is far more challenging than replication of established technologies and subject to much greater risk. The diffusion of successful innovation requires substantial financial commitments. These fund the investments that replace outdated products and processes and establish new organization structures, systems, and

[25] See the statistical data bases presented in the World KLEMS website: http://www.worldklems.net/data.htm
[26] See Jorgenson and Vu (2013),

business models. Innovation accounts for a relatively modest part of U.S. economic growth, but this is vital for maintaining gains in the U.S. standard of living in the long run.

Second, international comparisons of productivity levels are very promising for the analysis of sources of international competitiveness and the formulation of strategies for economic growth. In Section 6 we present international comparisons of productivity levels between Japan and the U.S. based on industry-level purchasing power parities. These provide important information on the under-valuation and over-valuation of the Japanese yen relative to the U.S. dollar.

The yen was under-valued, relative to the dollar, for three decades from 1955 until 1985, when the Plaza Accord produced an upward revaluation of the yen. Japan remained internationally competitive, despite a large productivity gap with the United States. The yen has been over-valued since 1985, relative to the dollar, reaching a peak in 1995 and greatly undercutting Japanese international competitiveness. After several years of monetary easing by the Bank of Japan the yen achieved purchasing power parity with the dollar in 2015 and restored Japan's international competitiveness.

A large productivity gap between Japan and the United States existed in 1955, but gradually closed until the collapse of Japanese real estate prices that signaled the end of the "bubble economy" in 1991. Japanese productivity has remained stagnant since that time, while U.S. productivity has continued to grow. The widening productivity gap between Japan and the U.S. can be traced to a relatively small number of trade and service sectors in Japan, but also includes agriculture. The contribution of manufacturing sectors to the productivity gap remains relatively small. We recommend formulating a growth strategy for Japan that will stimulate productivity growth in the Japan's lagging industrial sectors.[27]

[27] More details on recommendations for Japan's growth strategy are presented by Jorgenson (2016): http://scholar.harvard.edu/files/jorgenson/files/16_0316_jpec.pdf

Japan's highly competitive manufacturing industries should find new opportunities in both international and domestic markets under the devaluation of the yen by the Bank of Japan. Efforts to improve Japanese productivity should focus on industries in trade and services that are protected from international competition. Agriculture will require structural reform followed by an opening to trade.

Our overall conclusion is that the World KLEMS Initiative has been very successful in promoting the development of industry-level data sets on productivity and economic growth for economies around the world. These data have been incorporated into the official national accounts for a number of countries and have been documented by the OECD and the United Nations. These data have been used extensively in analyzing the sources of economic growth and the opportunities for promoting growth. International comparisons of productivity are far more challenging and require industry-level purchasing power parities. These comparisons are potentially very valuable in analyzing international competitiveness and formulating growth strategies in a highly competitive international environment.

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Figure 1. Contributions of Industry Groups to U.S. Value Added Growth, 1947-2012

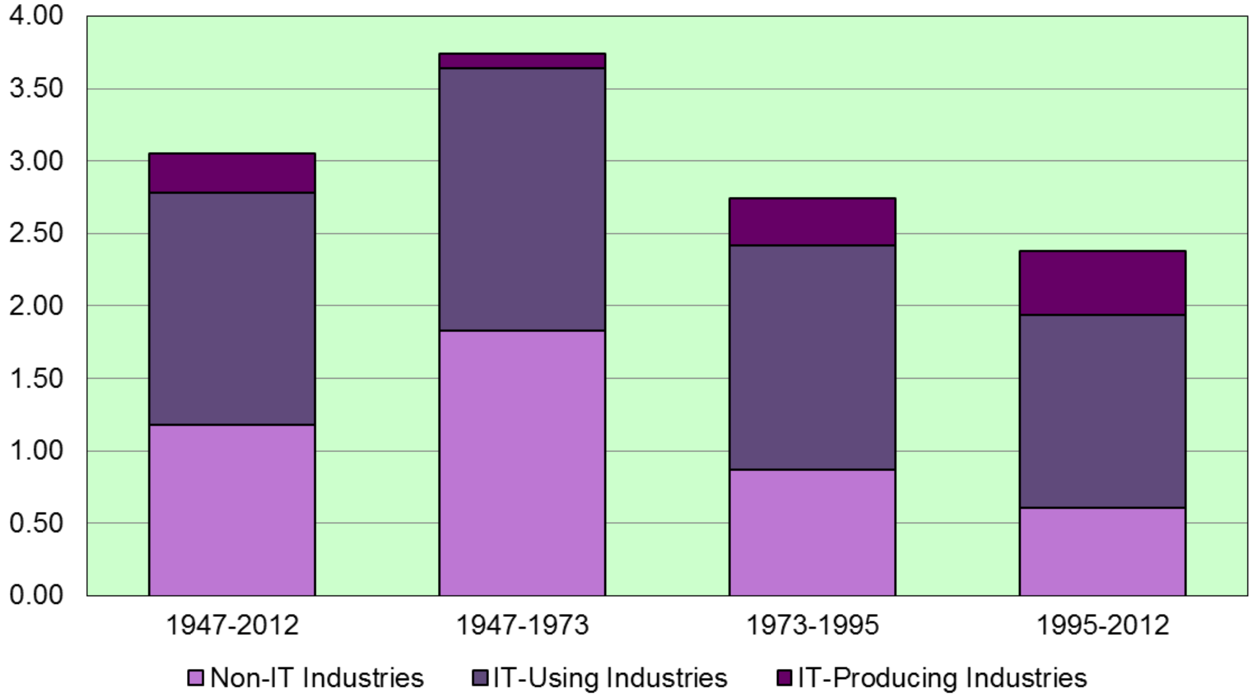

Figure 2. Contributions of Industry Groups to U.S. Value Added Growth, 1995-2012

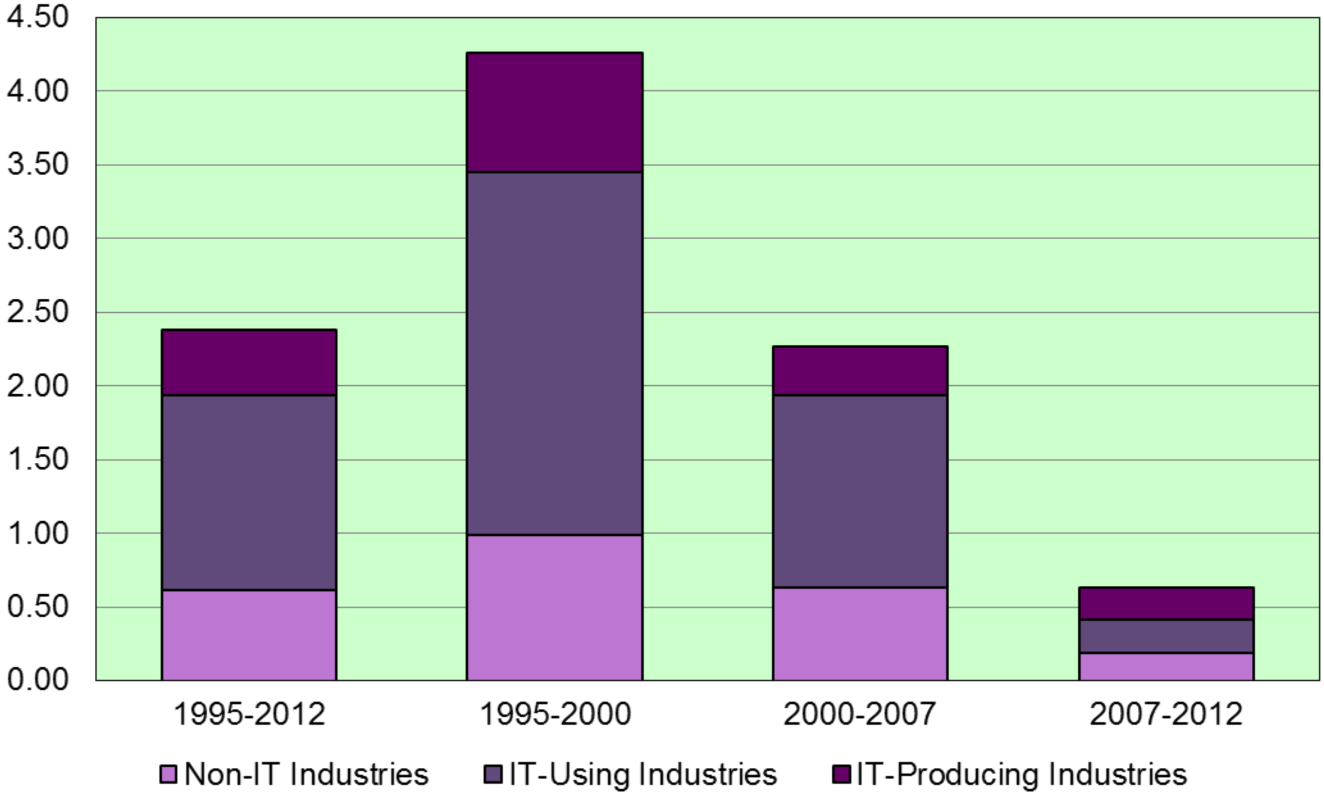

Figure 3. Industry Contributions to U.S. Value Added Growth, 1947-2012

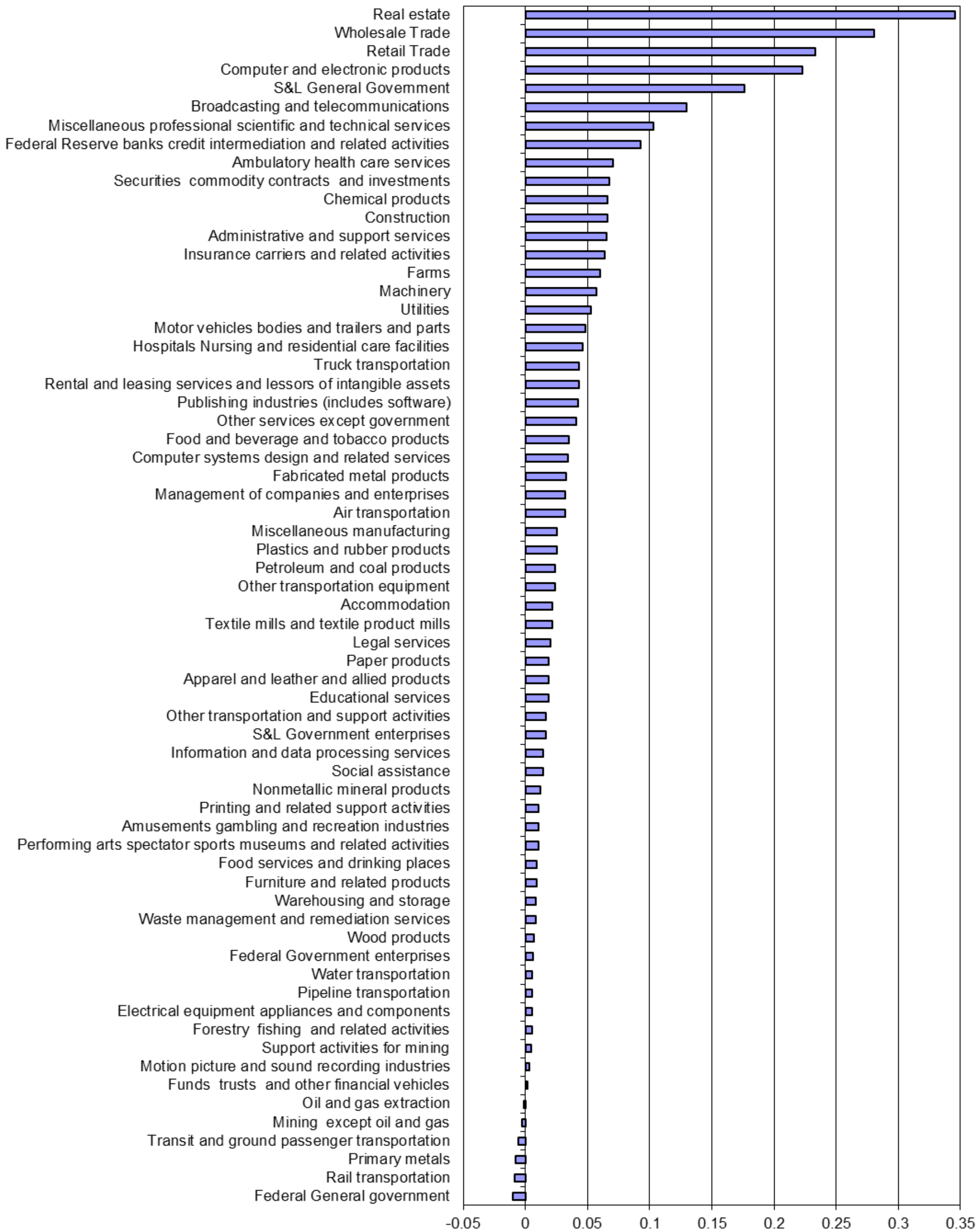

Figure 4. Contributions of Industry Groups to U.S. Productivity Growth, 1947-2012

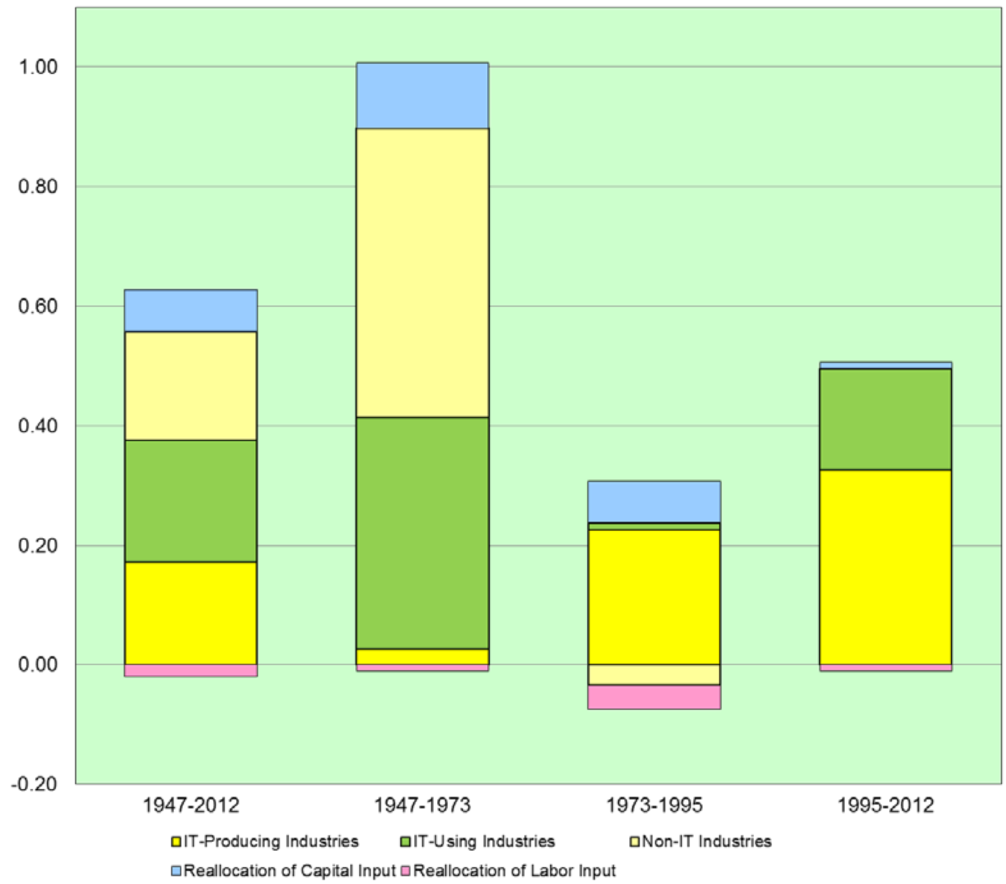

Figure 5. Contributions of Industry Groups to U.S. Productivity Growth, 1995-2012

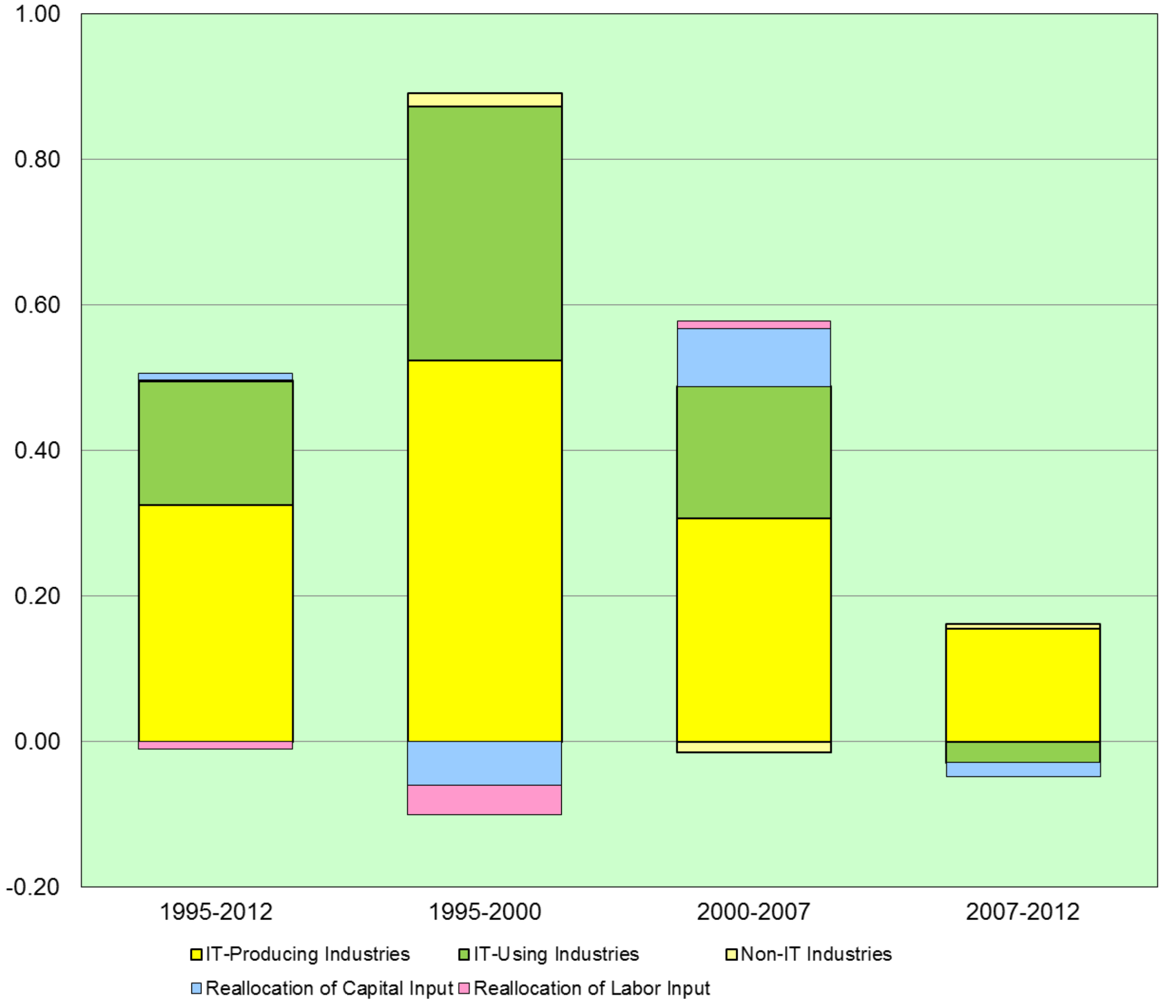

Figure 6. Industry Contributions to U.S. Productivity Growth, 1947-2012

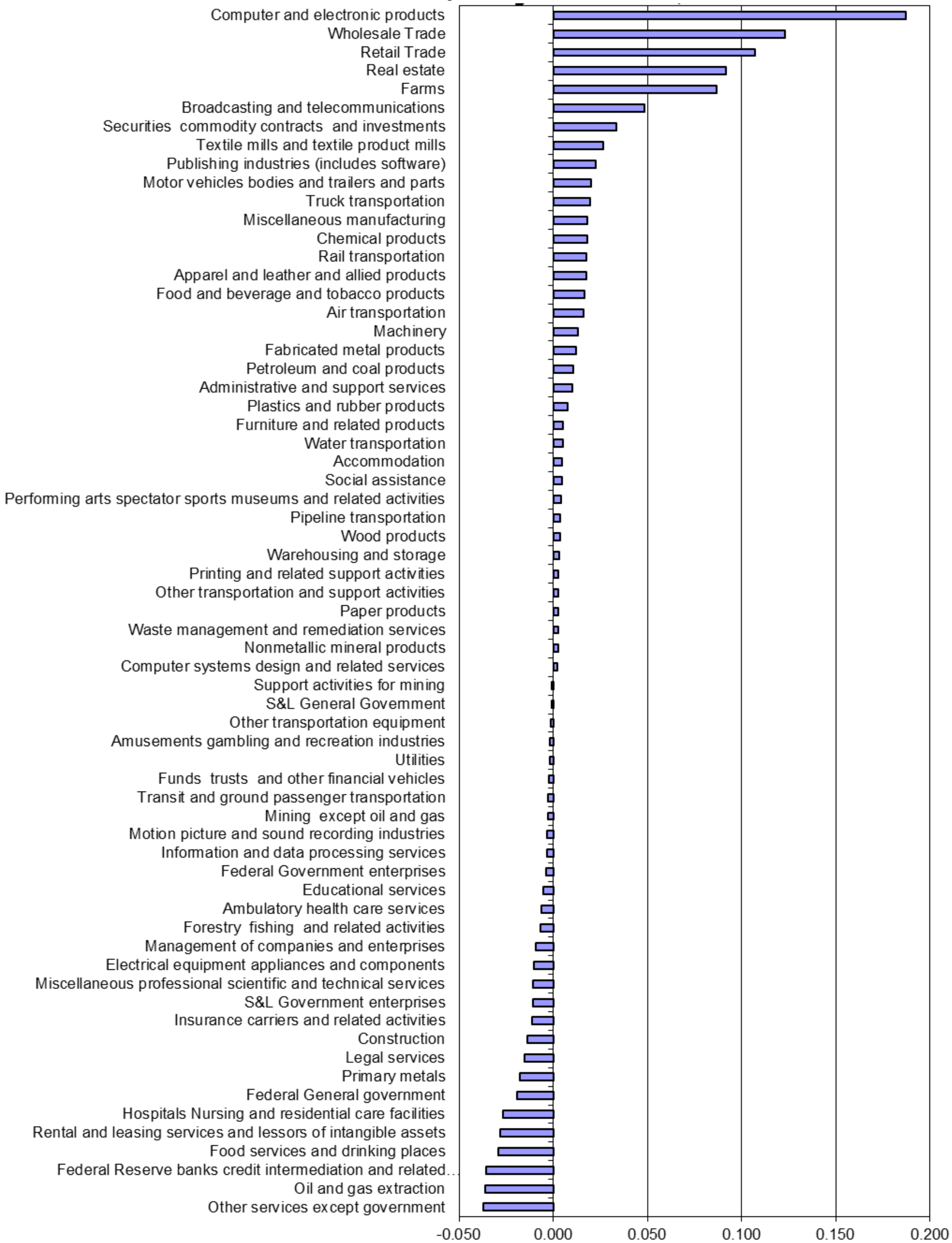

Figure 7. Sources of U.S. Economic Growth, 1947-2012

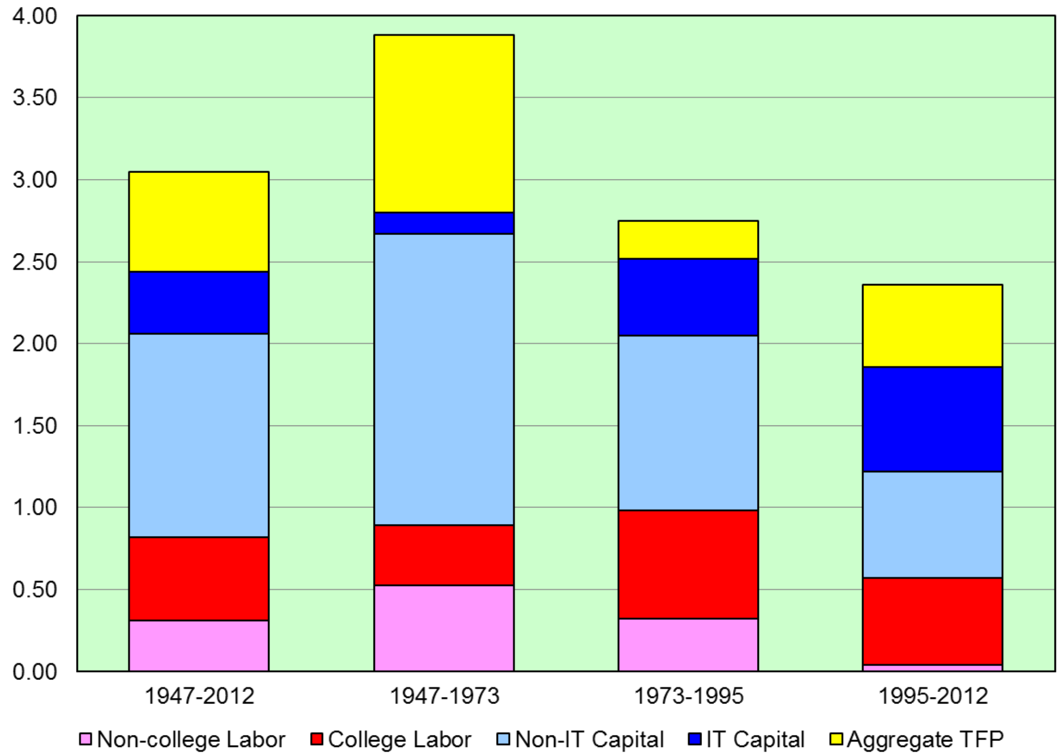

Figure 8. Sources of U.S. Economic Growth, 1995-2012

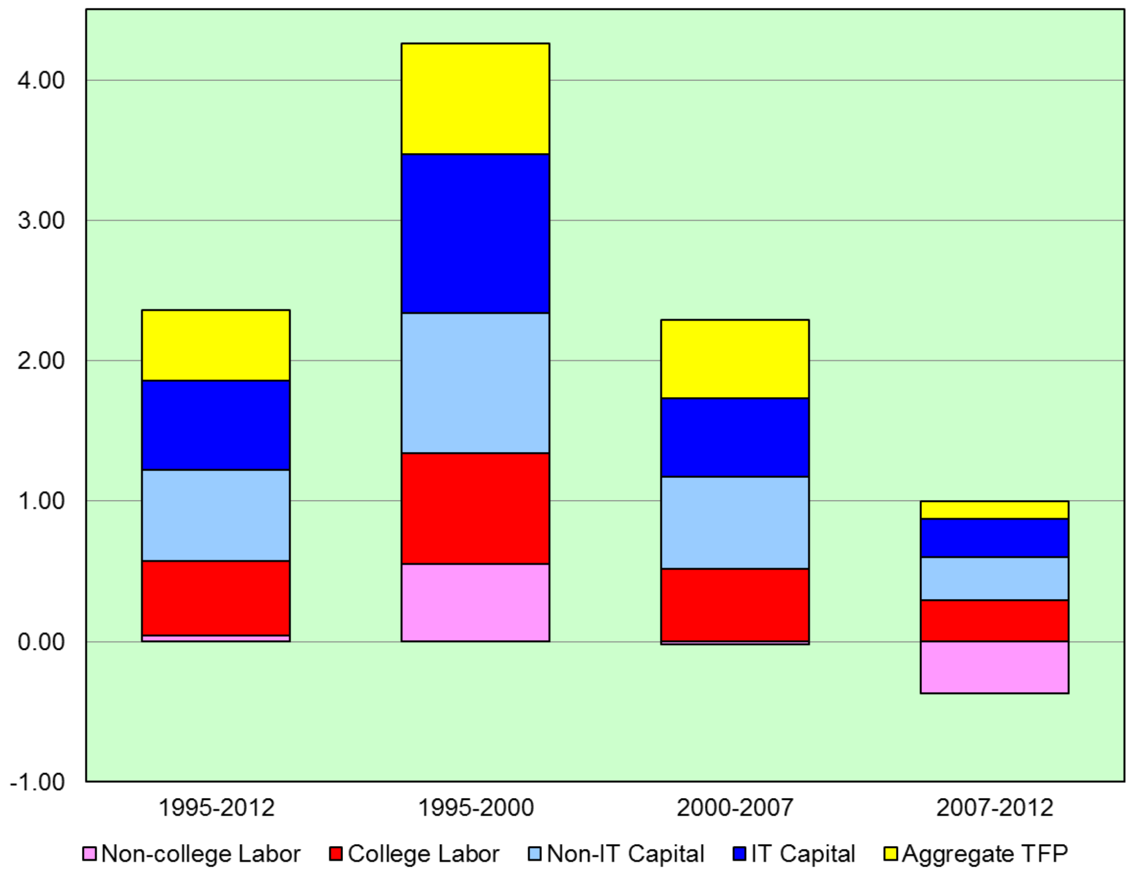

Table 1 : PPPs and Price Level Indices for Output and KLEMS

	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2012
PPPs (Purchasing Power Parities)													
Output (GDP)	210.2	215.1	237.0	247.3	279.4	247.3	206.8	185.1	164.3	146.3	124.9	114.0	107.3
Capital	166.6	235.7	217.9	291.2	222.4	227.2	207.9	194.4	145.7	141.9	125.0	112.7	103.2
Labor	60.7	66.2	101.5	123.6	200.2	178.4	153.3	147.7	144.6	114.1	90.4	79.2	75.4
Energy	627.4	625.1	618.9	581.6	600.6	521.3	461.1	308.9	271.9	231.1	169.1	151.3	143.8
Material	270.8	254.3	259.3	255.3	255.8	218.8	193.6	154.3	135.5	128.3	112.3	100.1	93.1
Service	175.2	168.3	197.4	206.4	259.7	246.3	205.6	181.7	163.0	142.5	122.6	108.4	103.3
ref) GDP-expenditure based	---	170.6	204.1	226.0	266.0	245.6	206.9	189.2	174.5	155.0	129.6	111.6	104.6
Exchange Rate	360.0	360.0	360.0	360.0	296.8	226.8	238.5	144.8	94.1	107.8	110.2	87.8	79.8
PLIs (Price Level Indices)													
Output (GDP)	0.58	0.60	0.66	0.69	0.94	1.09	0.87	1.28	1.75	1.36	1.13	1.30	1.34
Capital	0.53	0.74	0.68	0.90	0.83	1.09	0.93	1.40	1.59	1.32	1.14	1.29	1.30
Labor	0.17	0.18	0.28	0.34	0.67	0.79	0.64	1.02	1.54	1.06	0.82	0.90	0.95
Energy	1.74	1.74	1.72	1.62	2.02	2.30	1.93	2.13	2.89	2.14	1.53	1.72	1.80
Material	0.75	0.71	0.72	0.71	0.86	0.97	0.81	1.07	1.44	1.19	1.02	1.14	1.17
Service	0.49	0.47	0.55	0.57	0.88	1.09	0.86	1.25	1.73	1.32	1.11	1.24	1.29

Note: The PPP for GDP-output based is defined as a translog index of industry-level PPPs for value added, which is calculated by a double deflation method. The PLIs are defined as the ratio of PPPs to the annual average exchange rate (Tokyo Market Interbank Rate). The PPP and exchange rate are defined by Japanese Yen/ US Dollar. The PPP for GDP-expenditure based is the estimate by Eurostat-OECD.

Figure 9. Japan-U.S. Purchasing Power Parities for Output and KLEMS Inputs, 1955-2012

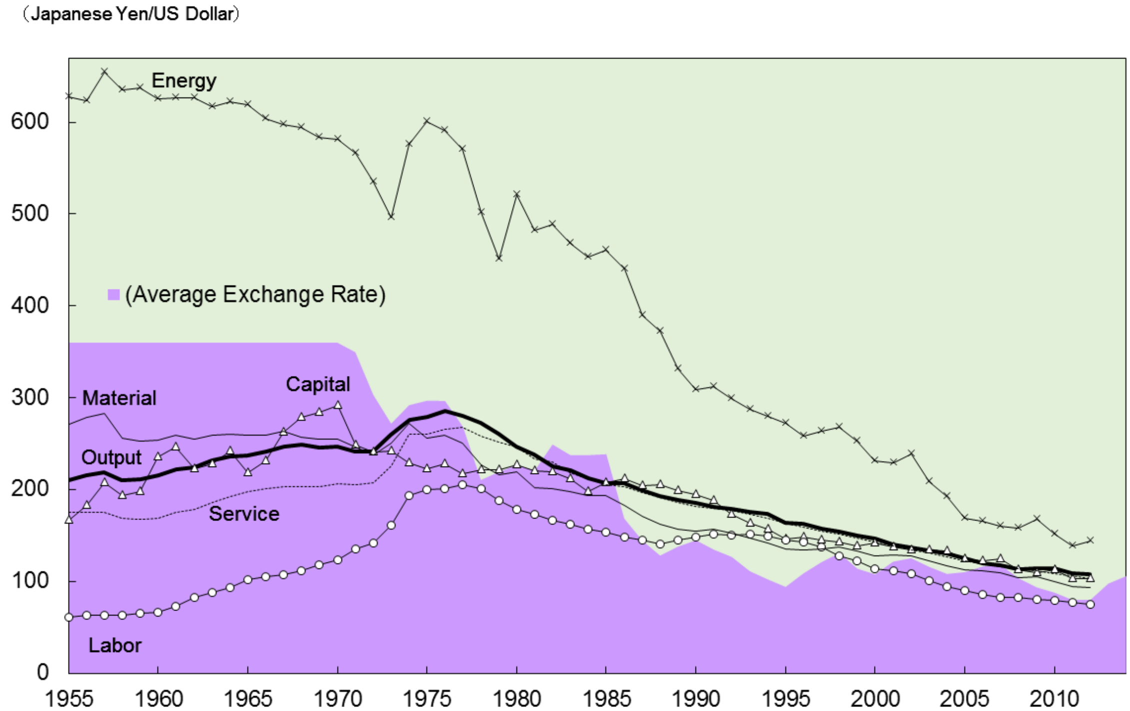

Figure 10. Industry Contributions to the Japan-U.S. Price Level Index, 2005

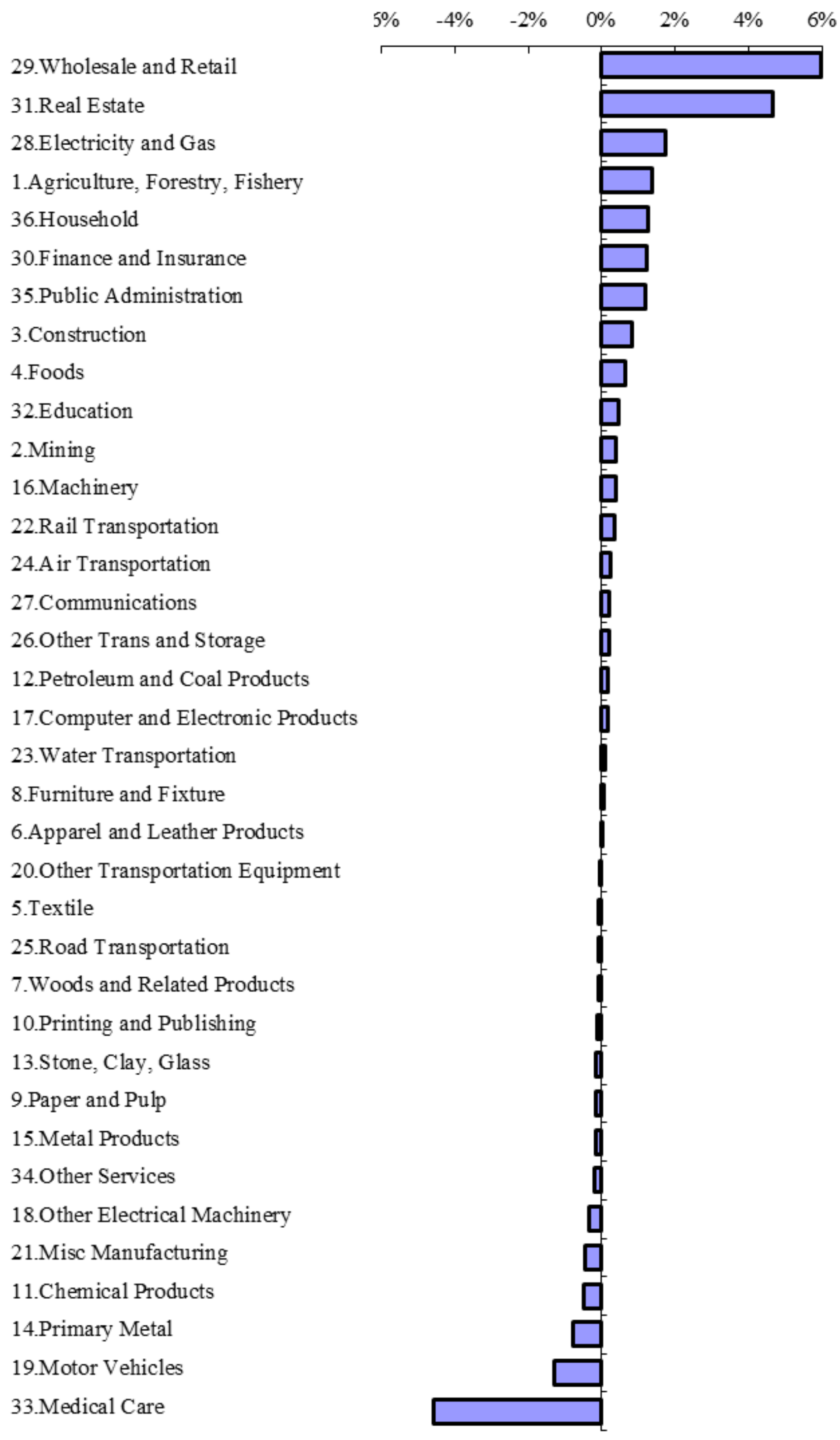

Table 2: Volume Level Indices of Output and Inputs and Productivity Level Indices

	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2012
Output	0.084	0.125	0.172	0.259	0.302	0.328	0.348	0.381	0.372	0.316	0.289	0.272	0.263
Output per Capita	0.155	0.239	0.336	0.508	0.583	0.637	0.684	0.770	0.790	0.703	0.668	0.657	0.646
Input per Capita	0.341	0.431	0.563	0.694	0.780	0.789	0.797	0.843	0.886	0.803	0.781	0.788	0.781
Capital Input per Capita	0.173	0.215	0.334	0.443	0.574	0.607	0.619	0.704	0.794	0.709	0.649	0.638	0.637
Capital Stock per Capita	0.319	0.380	0.502	0.616	0.727	0.792	0.816	0.853	0.928	0.932	0.919	0.916	0.909
Capital Quality	0.541	0.566	0.664	0.719	0.790	0.766	0.758	0.825	0.855	0.761	0.706	0.696	0.701
Labor Input per Capita	0.606	0.789	0.866	0.988	0.999	0.987	1.002	1.001	0.993	0.919	0.949	0.987	0.970
Hours Worked per Capita	1.051	1.288	1.308	1.391	1.298	1.225	1.210	1.172	1.150	1.042	1.061	1.097	1.090
Labor Quality	0.576	0.612	0.662	0.711	0.770	0.805	0.828	0.854	0.864	0.882	0.895	0.900	0.890
TFP	0.454	0.555	0.597	0.732	0.748	0.808	0.858	0.912	0.892	0.876	0.855	0.833	0.827
Average Labor Productivity	0.147	0.186	0.257	0.365	0.449	0.520	0.565	0.657	0.686	0.675	0.629	0.599	0.593
Average Capital Productivity	0.895	1.112	1.008	1.146	1.017	1.051	1.105	1.093	0.995	0.991	1.029	1.030	1.014

Note: All figures present the level indices (Japan/U.S.) in each period.

Figure 11. Japan and U.S. Total Factor Productivity Levels, 1955-2012

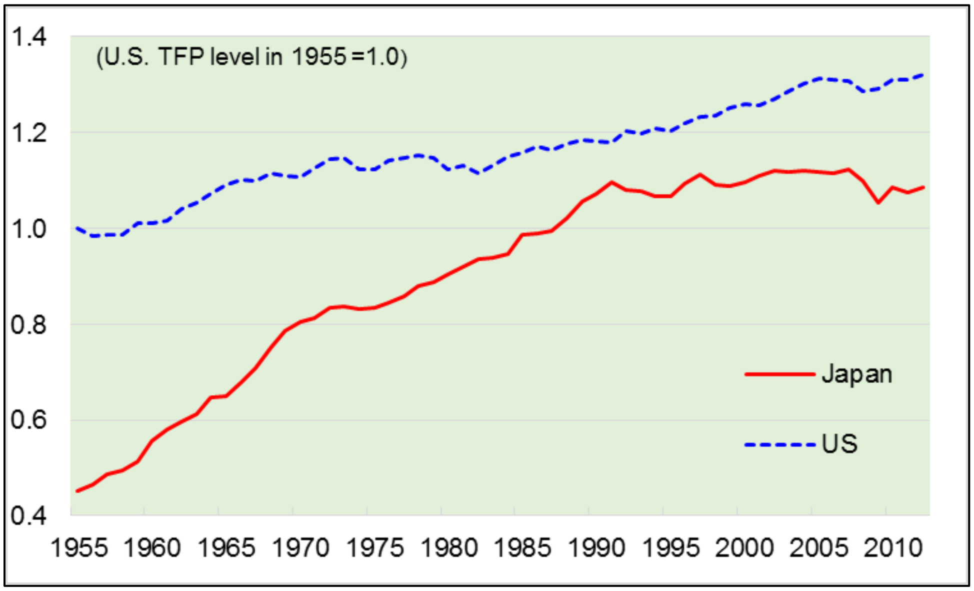

Table 3: Sources of Economic Growth in Japan and the U.S.

	1955-60	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1990-95	95-2000	2000-05	2005-10	2010-12	1955-91	91-2012
							Japan							
Output	10.45	11.16	11.97	5.82	4.97	4.45	5.33	2.00	1.14	0.96	-0.23	0.34	7.67	0.70
Capital Input	3.56	6.46	5.62	4.46	1.97	1.66	2.82	2.00	0.79	0.50	0.43	0.16	3.79	0.73
IT Capital	0.09	0.17	0.21	0.23	0.13	0.19	0.37	0.22	0.37	0.46	0.30	0.16	0.20	0.32
(of which quality)	0.00	0.01	0.00	-0.01	0.00	0.01	-0.02	0.00	0.02	0.05	0.02	-0.04	0.00	0.02
Non-IT Capital	3.47	6.29	5.41	4.23	1.85	1.48	2.45	1.77	0.42	0.04	0.13	0.00	3.59	0.40
(of which quality)	0.83	1.95	1.21	1.33	0.12	0.32	1.31	0.74	-0.21	-0.21	-0.02	0.13	1.04	-0.02
Labor Input	2.68	1.66	2.01	0.67	1.42	1.00	0.86	0.09	-0.17	0.07	-0.06	0.17	1.42	0.02
(of which quality)	0.94	1.02	0.72	1.08	0.78	0.56	0.47	0.36	0.38	0.35	0.33	0.02	0.78	0.33
TFP	4.22	3.03	4.34	0.70	1.58	1.79	1.65	-0.09	0.53	0.39	-0.60	0.00	2.46	-0.05
Agriculture	0.63	-0.10	-0.31	0.03	-0.12	0.09	0.04	-0.07	0.06	-0.07	0.01	0.03	0.03	-0.01
IT-manufacturing	0.08	0.13	0.15	0.15	0.22	0.17	0.28	0.12	0.35	0.29	0.10	-0.03	0.17	0.19
Motor Vehicle	0.17	0.11	0.27	0.04	0.24	-0.03	0.07	-0.04	0.00	0.09	-0.05	-0.05	0.12	-0.01
Other manufacturing	1.77	1.86	2.24	0.10	0.73	0.78	0.48	-0.02	0.07	0.00	-0.24	-0.37	1.12	-0.11
Commonucations	0.15	0.16	0.07	0.07	-0.02	0.05	0.08	0.07	0.10	0.01	0.02	0.07	0.08	0.05
Trade	0.73	1.05	0.88	0.23	0.70	0.02	0.64	0.66	-0.07	0.29	-0.39	0.04	0.62	0.06
Finance & Insurance	-0.05	0.29	0.24	0.20	0.23	0.15	0.29	-0.18	0.18	0.10	-0.19	-0.12	0.18	-0.02
Other services	0.73	-0.47	0.81	-0.12	-0.40	0.56	-0.22	-0.63	-0.17	-0.31	0.15	0.44	0.13	-0.20
							United States							
Output	2.51	4.78	3.74	2.74	3.31	3.29	3.51	2.47	4.40	2.79	0.96	2.12	3.33	2.71
Capital Input	2.00	2.30	2.79	2.10	1.92	1.83	1.98	1.44	2.40	1.78	1.04	0.69	2.11	1.59
IT Capital	0.05	0.11	0.16	0.16	0.29	0.42	0.48	0.51	1.02	0.56	0.36	0.21	0.24	0.58
(of which quality)	-0.09	0.14	0.05	0.04	0.09	0.14	0.14	0.16	0.29	0.14	0.07	0.03	0.07	0.15
Non-IT Capital	1.95	2.19	2.63	1.94	1.63	1.41	1.50	0.93	1.38	1.22	0.68	0.48	1.87	1.00
(of which quality)	0.59	0.26	0.42	0.51	0.35	0.35	0.53	0.24	0.49	0.53	0.12	-0.02	0.42	0.32
Labor Input	0.31	0.92	0.67	0.37	1.38	0.86	1.11	0.65	1.12	0.15	-0.01	1.04	0.76	0.59
(of which quality)	0.28	0.24	0.02	0.20	0.21	0.22	0.13	0.21	0.14	0.20	0.27	0.28	0.19	0.21
TFP	0.20	1.55	0.28	0.27	0.01	0.60	0.41	0.38	0.89	0.86	-0.07	0.39	0.46	0.53
Agriculture	0.12	0.04	0.03	0.02	-0.05	0.24	0.05	-0.01	0.07	0.02	0.00	-0.08	0.06	0.01
IT-manufacturing	-0.03	0.09	0.07	0.14	0.20	0.21	0.20	0.28	0.52	0.19	0.15	0.03	0.13	0.26
Motor Vehicle	-0.04	0.12	-0.07	0.01	-0.03	0.05	-0.03	0.05	0.01	0.05	0.01	0.06	0.00	0.03
Other manufacturing	-0.14	0.60	0.15	-0.10	-0.01	0.26	0.16	0.04	0.03	0.14	-0.08	-0.08	0.12	0.02
Commonucations	0.00	0.05	0.02	0.04	0.14	-0.02	0.04	0.00	-0.02	0.11	0.01	-0.02	0.04	0.03
Trade	0.13	0.23	0.14	0.38	-0.08	0.34	0.15	0.21	0.48	0.21	-0.12	-0.07	0.19	0.16
Finance & Insurance	0.00	-0.05	-0.09	-0.06	0.12	-0.17	-0.03	-0.02	0.12	0.08	-0.04	-0.01	-0.04	0.03
Other services	0.16	0.48	0.03	-0.15	-0.27	-0.31	-0.12	-0.17	-0.31	0.05	0.01	0.56	-0.04	-0.02

Note: All figures present the average annual growth rates in each period.

Figure 12. Japan-U.S. Total Factor Productivity Gaps, 1955-2012

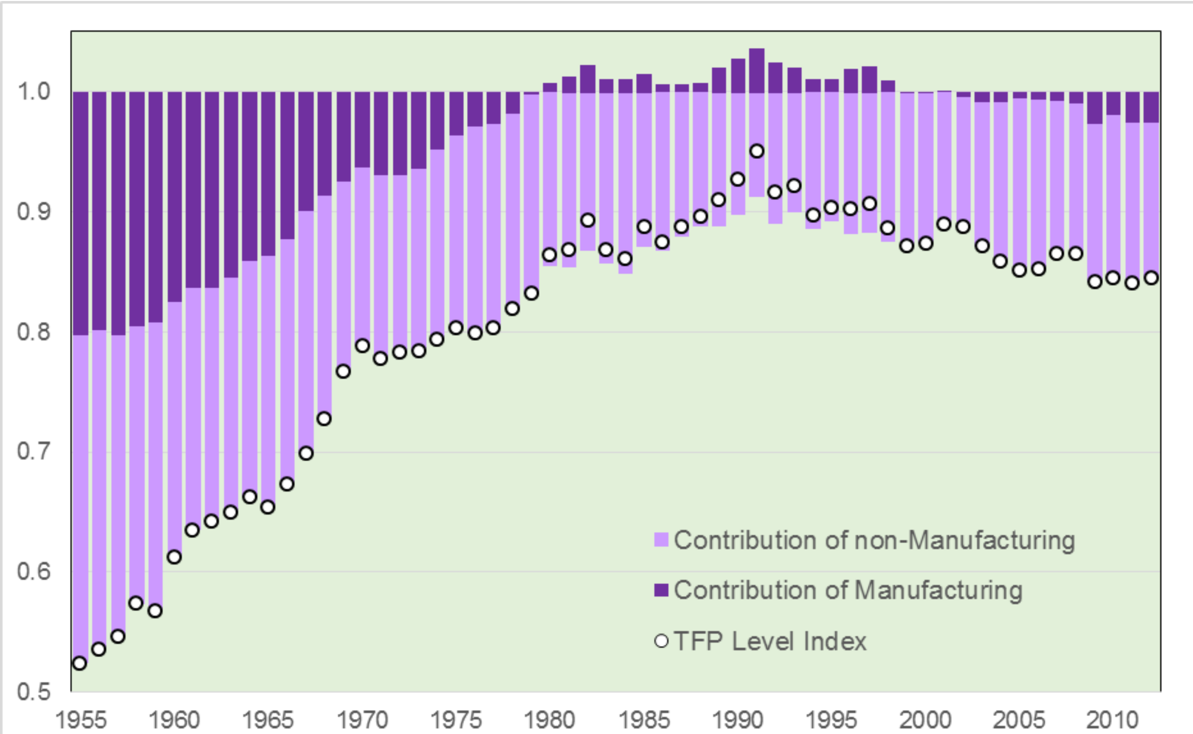

Figure 13. Industry Contributions to the Japan-U.S. Total Factor Productivity Gap, 2005