Progress on Measuring the Industry Origins of the Japan-U.S. Productivity Gap

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Abstract

This paper reports recent progress in measuring price level indices and productivity gaps for Japanese and U.S. industries between 1955 and 2015. We discuss the conceptual issues involved, document the data requirements, and describe improvements in the data and methods since our earlier work, reported in Jorgenson, Nomura, and Samuels (2016). The major improvement is new benchmark purchasing power parity (PPP) estimates for outputs and KLEMS inputs by industry for the year 2011. Based on price level indices from our updated data set, we find that Japan lost price competitiveness with the U.S. in the 1990s, but regained competitiveness by 2015, driven by depreciation of the Japanese Yen. The dynamics of the productivity gap were notably different from the aggregate price level index, as efficiency of production in the U.S. exceeded that in Japan for the entire postwar period. In the 1980s and the 1990s, however, TFP in manufacturing in Japan overtook productivity in the U.S. by a substantial margin. Over that same period, the gap in non-manufacturing TFP diminished, but not at the same rate as in manufacturing industries. Between 1991 and 2015, U.S. TFP growth exceeded that of Japan in manufacturing. Because the gap in non-manufacturing TFP remained stable over the period, the overall gap productivity gap widened over the period. In 2015, the gap in manufacturing productivity was close zero, while the remainder of the aggregate TFP gap was mostly accounted for by lower productivity in Japan of the Wholesale and Retail and Other Services industries.

Keywords**:** Purchasing Power Parity, Productivity, Growth.

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1 Introduction

In this paper we analyze competition between Japanese and U.S. industries. This has provided powerful incentives for mutually beneficial international economic co-operation across the Pacific since Japan regained sovereignty in 1952. The first objective is to present price level indices and productivity gaps between Japan and the U.S. for the period 1955–2015. The price level index is the principal indicator of international competitiveness, often expressed in terms of the over- or undervaluation of currencies. The productivity gap is an indicator of the relative efficiency with which inputs like capital and labor are transformed into output in the two economies. A key feature of our measures is that they are constructed within the framework of the national accounts of both countries. We begin 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. The 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 Japanese yen and the U.S. 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 2011 was 109.7 yen per dollar, based on new benchmark estimates developed in this paper, while the market exchange rate was 79.8 yen per dollar on average. The price level index was 1.37, so that the yen was over-valued relative to the dollar by 37 percent. Firms located in Japan had to overcome this price disadvantage in international markets to compete with U.S. producers. This gives a quantitative measure of the international competitiveness of Japan and the U.S. in 2011.

The first contribution of this paper is to develop new estimates of price level indices for 36 industries in Japan and the U.S., including households (sector 36) producing capital services of owner-occupied housing and consumers' durables. Our estimates are derived from detailed purchasing power parities for 174 products, constructed within the framework of a bilateral Japan-US input-output table for the new benchmark year of 2011. We also develop price level indices for capital stock and capital services for 1224 categories, classified by type of assets (34), including research and development, land, and inventories, and industry (36) categories. Finally, we develop price level indices for 1680 categories of labor inputs, cross-classified by gender (2), age (6), education attainment (4), and industry (35) categories, excluding households. We aggregate the detailed price level indices to construct measures for outputs and for capital (K), labor (L), energy (E), materials (M), and services (S) inputs for the 36 industries.

Jorgenson and Nomura (2007) constructed price level indices for 42 industries for the period 1960–2004. They showed that the price level index for Japan and the U.S. captures a critical turning point in the international competition between the two economies. The Plaza Accord of 1985 was an agreement among the five leading industrialized countries in response to the large U.S. current account deficits in the 1980s. This resulted in depreciation of the U.S. dollar and rapid appreciation of the Japanese yen. The revised estimates for 2011 presented in this paper are broadly consistent with Jorgenson and Nomura (2007). We estimate that the yen was undervalued by 20 percent relative to the dollar in 1985, although this was a significant appreciation from 51 percent undervaluation in 1955. The rapid strengthening of the yen reversed this relationship, leading to an overvaluation by 26 percent in 1991. The revaluation of the yen continued through 1995, leading to an overvaluation of the yen of 66 percent and a dramatic loss in Japanese international competitiveness.

After 1995 Japanese policy makers spent more than a decade dealing with the overvaluation of the yen. Domestic deflation and a modest devaluation coincided with a price level index decline of 4.2 percent annually from 1995 through 2007. A fall in the purchasing power parity of 2.3 percent per year resulted from modest inflation of 1.7 percent in the U.S. and deflation in Japan of 0.6 percent. In addition, the yen-dollar exchange rate fell by 1.9 percent per year, almost reaching the yen-dollar purchasing power parity in 2007.

The financial and economic crisis that originated in the U.S. in 2007–2009 led to a second sharp revaluation of the yen. Under Chairman Ben Bernanke, the Federal Reserve vastly expanded its balance sheet through quantitative easing but the Bank of Japan under Governor Masaaki Shirakawa failed to react. The yen appreciated to a historic high of 75.5 yen to the dollar in November 2011. Subsequently there was a modest depreciation of the yen, but in 2012 the yen was still overvalued by 36 percent. The election of Prime Minister Shinzo Abe in December of 2012 coincided with further depreciation of the yen. This accelerated with the adoption of quantitative easing by the Bank of Japan after Governor Haruhiko Kuroda took office in April 2013. In 2015 the yen-dollar exchange rate had risen to 121.0 yen per dollar, well above our estimate of the purchasing parity of 109.3 yen per dollar. We conclude that quantitative easing by the Bank of Japan has restored Japan's international competitiveness relative to the United States.

Price level indices between Japan and the U.S. have real counterparts in the productivity gaps between the two countries. We define productivity as output per unit of all inputs. 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 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.

The second contribution of this paper is to trace the Japan-US productivity gap to its sources at the industry level. For this purpose we use new industry-level production accounts for Japan and the U.S. that are closely comparable and employ similar national accounting concepts. The U.S. production account was developed by Jorgenson, Ho, and Samuels (2015), who have extended the estimates of Jorgenson, Ho, and Stiroh (2005) backward to 1947 and forward to 2015. We revise and extend the Japanese production account presented by Jorgenson and Nomura (2007) backward to 1955 and forward to 2015 with important revisions described below. We construct productivity gaps at the industry level that account for bilateral differences in productivity in the benchmark year.[1]

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), and Cameron (2005), Jorgenson and Nomura (2007), as well as Jorgenson, Nomura and Samuels (2016). We define the productivity gap between Japan and the U.S. 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

[1] This stands in contrast to a method that assumes productivity in the benchmark year is the same in both countries and extrapolates using country-level productivity accounts.

Japan regained sovereignty at the end of the Allied occupation in 1952, Japan's TFP was 51 percent of the U.S. level, so that the productivity gap between the two economies was 49 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 1955–1971, considerably exceeding the income-doubling rate of seven percent. The growth of TFP records 3.1 percent per year on average, contributing about 31 percent of this growth in output. The first oil shock of 1973 slowed Japanese growth considerably. Japanese TFP grew at 1.3 percent per year from 1971 to 1991, while annual U.S. TFP growth averaged only 0.2 percent. By 1991 Japanese TFP reached 95 percent of the U.S. level, narrowing the productivity gap from 49 percent in 1955 to 5 percent in 1991.

The collapse in Japanese real estate prices that ended the "bubble economy" in 1991 ushered in a period of much slower growth, often called the Lost Decade. Hamada and Okada (2009) have employed price level indices to analyze the monetary and international factors behind Japan's Lost Decade.[2] The Lost Decade of the 1990s in Japan was followed by a brief revival in economic growth in the middle 2000's. However, the Japanese rate of economic growth plummeted to only 0.4 percent per year from 1991–2009. U.S. economic growth continued at 2.9 percent in the same period, powered by the information technology investment boom of 1995–2000, when the growth rate rose to 4.5 percent per year. After 1991 Japanese TFP has been falling at 0.3 percent per year, while U.S. TFP growth continued at 0.4 percent. The Great Recession of 2007–2009 in the U.S. led to a sharp appreciation of the yen in response to quantitative easing by the Federal Reserve. This resulted in a downturn in Japan that was more severe than in any of the other major industrialized countries. In 2009 Japan-U.S. productivity gap had widened to 17 percent, the level of the early 1980's.

After 2009, Japanese economic growth recovered to the pace of 1.3 percent per year through 2015. While this recovery in production is relatively weak, it is similar to growth in the Lost Decade of 1990's, and is slower than the U.S. growth of 2.2 percent over this period.

[2] The Lost Decade is discussed in greater detail by Hamada, Kashyap, and Weinstein (2010) and Iwata and ESRI (2011).

However, since the labor and capital inputs are almost stable in this period in Japan, almost all of the Japanese economic growth was realized by TFP improvement of 1.2 percent per year. This contributed to narrowing the Japan-U.S. productivity gap. The TFP gap is narrowed by 4 percentage points from 17 percent in 2009, but an ample productivity gap remains in 2015.

In summary, this paper analyzes changes in price competitiveness between Japan and the U.S. and the industry origins of the productivity gap between the two economies for six decades beginning in 1955. In Section 2 we describe the data sources for comparing outputs, inputs, and productivity at the industry level and constructing price level indices at elementary and industry levels. In Section 3 we present the resulting price level indices and productivity gaps. We aggregate these results to obtain indices of output, capital and labor inputs, and TFP for Japan and the U.S. Section 4 concludes the paper. We present our methodological framework in the Appendix.

2 Data

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

Industry-level production accounts for Japan and the U.S. include industry outputs, factor inputs of capital and labor, and intermediate inputs of energy, materials, and services (KLEMS). We present these data in current and constant prices for the period 1955–2015. Productivity for each industry is defined as the ratio of output to all inputs. Jorgenson, Ho, and Samuels (2015) provide details on the data sources and methods of data construction for the U.S. Adjustments to the U.S. data to ensure consistency between Japan and the U.S. are noted below.

Our industry-level production accounts for Japan take the study by Jorgenson and Nomura (2007) as a point of departure. We have made four major improvements in the data for Japan. The first is greater consistency with the production accounts and commodity flow data from the Japan's System of National Accounts (JSNA). These accounts are compiled by the Economic and Social Research Institute (ESRI) in the Cabinet Office of Japan. The 2011 benchmark revision of the JSNA was published in 2016 and followed the United Nations' *System of National Accounts 2008* (SNA 2008). We have incorporated commodity flow data from the JSNA.[3]

Second, the estimates of labor services by Jorgenson and Nomura (2007) were based on a

[3] We are indebted to Mr. Shuji Hasegawa and Mr. Hidehiko Futamura, ESRI, for the unpublished commodity flow data from the JSNA for the period 1994–2015.

limited number of published cross-tabulations, supplemented by sample surveys of educational attainment. Nomura and Shirane (2014) have replaced these sources by custom-made tables with fully cross-classified data for 1980–2010 from the Japanese Census of Population[4] and have provided a comprehensive revision of Japanese labor data by industry, with new estimates extended backward to 1955 and forward to 2015.

Third, we replace rates of depreciation for produced assets in the JSNA by new estimates developed by Nomura and Suga (2018) at ESRI. They have estimated asset lives and rates of depreciation for a very finely divided classification of assets. This classification distinguishes 369 asset types and uses data on retired assets collected in ESRI's *Survey on Capital Expenditures and Disposals in Japan* from 2006 to 2014. The survey collected observations on 1.1 million asset disposals from business accounts of private corporations. These data were used to estimate asset lifetimes. For 84 thousand observations the assets were sold for continued use and the prices were used to estimate rates of deprecation.

Fourth, we have defined the supply and use tables (SUT) at basic prices. Consumption taxes are removed in our compilation of intermediate inputs and factor services. The consumption tax was first introduced in Japan in April 1989. Both deductible and non-deductible consumption taxes are included in indirect taxes in the official benchmark input-output tables and production accounts in the JSNA. By removing these taxes we are able to provide purchasing power parities for Japan-U.S. comparisons that reflect prices received by the producers.

The public sector is a special challenge in creating a common industry classification. In principle, the public sector should include only sectors where market transactions are not available. In practice, we arrive at our common classification by allocating a portion of public sector activities to private industries with similar technological characteristics. In particular, we move U.S. government enterprises to their counterpart industries in the private sector. The value of non-market production of capital services by households and governments are imputed and are defined as the outputs of governments (sector 35) and households (sector 36). We set the productivity gap between Japan and the U.S. equal to zero for the non-market production of capital services by households and the public sector.

[4] These tables have been compiled at five-year intervals by the National Statistics Center, which is an incorporated administrative agency created in April 2003 as part of the central statistical organization in Japan. Unpublished tabulations of fully cross-classified data for Japan were made available through full implementation of the Statistics Act implemented in April 2009.

The industry-level production accounts for Japan and the U.S. are closely comparable. The required rates of return used in measuring prices and volumes of capital services are determined endogenously to exhaust capital income across all capital assets. The industry-level measures of labor services are adjusted for quality, using detailed cross-classifications of the labor data. For this study we have developed a 36-industry classification that provides greater comparability for the period 1955–2015 than the 42-industry classification for 1960–2004 employed by Jorgenson and Nomura (2007).

2.2 PPPs for Elementary Products

We estimate purchasing power parities (PPPs) for Japan and the U.S. for outputs, factor inputs of capital and labor, and intermediate inputs of energy, materials, and services (KLEMS) for 36 industries. Except for labor services, these PPPs are based on price comparisons of 174 elementary products for the benchmark year 2011. The elementary product refers to the most detailed level at which we have the data to define prices of comparable products in the two countries. This section describes the concepts and the multitude of data sources used for the elementary price comparisons. Section 2.3 describes the industry-level PPPs for output and intermediate inputs. The industry-level PPPs for capital and labor services are presented in Sections 2.4 and 2.5, respectively.

In this paper we use a hybrid of the two basic approaches for defining PPPs for elementary products, following Nomura and Miyagawa (2015). The first approach uses production-side data for domestically produced products in Japan and the U.S. The PPPs in producer's prices are ratios of average unit prices, each defined as the monetary value over the physical volume. This approach is especially easy to implement in sectors with outputs defined in homogenous physical units, for example, electricity and mining products. In the second approach PPPs can be estimated from demand-side data by eliminating the wedges between producer's domestic prices and purchaser's prices of composites of domestic and imported products. This approach is based on the 2011 PPP estimates for final demands developed in Eurostat-OECD (2012)[5] and the price model under the 2011 Japan-US bilateral input-output table (BIOT). The table for 2011 is extrapolated by the 2005 Japan-US table published by the Ministry of Economy, Trade and Industry (METI). We are able to account for differences in freight and insurance rates, duty rates,

[5] We are indebted to the Statistics Directorate of the OECD for the use of the most detailed PPP data at basic heading level.

wholesale and retail trade margins, transportation costs (railway, road, water, air, and others), and import shares of each commodity in Japan and the U.S. in 2011. Using demand-side data for purchaser's price PPPs for final demands, the producer's price PPPs for domestically produced goods are estimated, using the accounting model and data from the 2011 BIOT.[6]

One of the difficulties in estimating PPPs in producer's prices from demand-side data is to define PPPs for imported goods. These are required to separate PPPs for domestically produced commodities from PPPs for composite products that include imports. Using the Japan-US BIOT, goods purchased in Japan can be separated into domestically produced goods, goods imported from the U.S., and goods imported from the rest of the world (ROW). The purchaser's prices in Japan for goods imported from the U.S. can be linked to prices of domestically produced goods in the U.S. This involves taking account of the wholesale margins and transportation costs in the U.S., the costs of freight and insurance required for shipment from the U.S. to Japan, the duties levied by Japanese customs, and the margins for wholesale and retail trade and transportation costs in Japan. Similarly, import prices in the U.S. can be linked to domestic output prices in Japan. The prices of imports in Japan and the U.S. from the ROW are not readily observable and we develop a sub-model to determine these prices. The price level indices for domestically produced goods and composite goods are determined simultaneously within the framework of the Japan-US BIOT.

Another barrier to estimation of PPPs from demand-side data is the absence of price comparisons for intermediate products like semiconductors that do not appear in final demands. Although semiconductors play a significant role in productivity comparisons, PPPs are not provided in even the most comprehensive demand-side data, the Eurostat-OECD Purchasing Power Parities (2012). To supply the missing information, METI has carried out a *Survey on Disparities between Domestic and Foreign Prices of Industrial Intermediate Inputs* since 1994. Price differences are defined as purchaser's prices, including the difference in trade margins for intermediate goods. Using these data, the PPPs for domestically produced goods are estimated to

[6] Trade margins are one of the key variables in estimating PPPs for domestically produced goods. Nomura, Miyagawa, and Arai (2017) estimate that the trade margins in the Japan's 2011 Benchmark Input-Output Table were underestimated by about 30 percent and proposed revised estimates of margins at the elementary level. These revised estimates are used in our study. For defining PPPs from demand-side prices, the underestimation of margin rates induces overestimation in the PPPs for domestically produced goods in manufacturing sectors and the underestimation in the PPPs for production of wholesale and retail trade. As a whole it tends to overestimate PPP for output-based GDP. By using the revised estimates of margin rates from Nomura, Miyagawa, and Arai (2017), our estimates of PPP for output-based GDP approach the Eurostat-OECD (2012) estimate of PPP for expenditure-based GDP.

be internally consistent based on the accounting identities in the Japan-US BIOT. The accounting model allows us to strip the trade margins from the purchaser's prices in our estimates of price relatives for intermediate products. These approaches are incorporated into our new estimates of PPPs for 174 products in the benchmark year 2011.

2.3 PPPs for Outputs and Intermediate Inputs

We have defined five types of elementary Purchasing Power Parities (PPPs) for each of 174 products: (1) the producer's price PPP for domestically produced goods, excluding net indirect taxes, (2) the producer's price PPP for composite goods sold to households for household final demands, (3) the producer's price PPP for composite goods sold to industry, (4) the purchaser's price PPP for composite goods sold to households, and (5) the purchaser's price PPP for composite goods sold to industry. We use the PPPs for domestically produced goods (1) for outputs, the producer's price PPP's for composite goods sold to industry (3) for intermediate goods, and the purchaser's price PPP's for composite goods sold to industry (5) for investment expenditures.

Because product components may differ considerably within the same industry, it is crucial to use the harmonized product-level BIOT. METI's Japan-US BIOT provides the estimates of the symmetric product-by-product table. The estimation of industry level PPPs for outputs follows these two steps. First, we aggregate the 174 elementary level PPPs into the 36 industry level PPPs for outputs, using the translog price index for the benchmark year 2011, as presented in Equation (5) in the Appendix. The weights are the average shares of each industry's output in the two economies from the 2011 Japan-US BIOT. These estimates measured under the symmetric BIOT are treated as the product level PPPs in our bilateral productivity accounts. Second, we aggregate these estimated product level PPPs to industry level PPPs for outputs in Japan and the U.S. productivity accounts by means of a translog index, using the weights of the average shares of product's output in each industry, measured in Use/Make tables in Japan and the U.S.

Similarly, we aggregate industry-level PPPs for intermediate inputs by means of translog indices from the 174 elementary level PPPs, using the average shares as weights.[7] Given the

[7] In our bilateral productivity accounts, all inputs of energy purchased by energy conversion sectors – petroleum refining, electricity, and gas supply – are treated as materials input, not energy inputs.

industry-level PPPs for gross output and intermediate inputs, the industry-level PPPs for value added are measured by a double deflation method. The PPPs for non-market production in the government and household sectors set the Japan-US productivity gap equal to zero in these sectors.

2.4 PPPs for Capital Inputs

Our first step in measuring PPPs for capital inputs is to construct a common asset classification for Japan and the U.S. Our asset classification employs 34 assets, including three intellectual property products – R&D, mineral exploration, and software–, land, and inventories.[8] To measure PPPs for the acquisition of each asset, we construct translog indices of the purchaser's price PPPs for the composite goods by asset. These indices are based on our estimates for elementary level PPPs for the 174 products described above. The PPPs for acquisition of inventories are assumed to be the average of PPPs for acquisition of produced goods, except for buildings and construction.

The difference in land prices between Japan and the U.S. has a substantial impact on the PPPs for capital inputs. Since 1990, there has been a drastic change in price level indices for land. The price of land in Japan fell sharply during the real estate price collapse of 1991 that ended the "bubble economy". Our estimate of the average price of land in 2011 is only 34 percent of that in 1990. In contrast, the U.S. land price increased substantially from the beginning of the 2000s, so that the average price reached to 3.7 times higher than that in 1990 at its peak in 2005. The average price by 2011 has decreased to a similar level of that in 1990. As the bilateral comparisons of land price/value, the *Survey on Actual Conditions Regarding Access to Japan* and *The World Land Value Survey* were provided by the Japan External Trade Organization (JETRO) and the Japanese Association of Real Estate Appraisal (JAREA), respectively. Based on the JETRO survey, the Japan's land price for industrial use with similar conditions is 7.6 times higher than that in the U.S. in 1998. In JAREA survey, Japan's land price for commercial use is valued at 2.4 times the average price in 2011. Reflecting these changes in both countries and the price differentials, the price differential for land between Japan and the

[8] In 2011 the R&D stock at current prices accounts for 5.7 percent of the total capital stock, including land and inventories, in Japan and 5.5 percent in the U.S. The shares of software stock are 1.7 percent and 2.0 percent, respectively. Although the shares of intellectual property products are similar, there is a sharp contrast in the land stock share, as 41.8 percent in Japan and 14.0 percent in the U.S.

U.S. is evaluated as 3.1 times higher in our new benchmark estimates for 2011. The price for acquisition of fixed assets, produced assets and land, in Japan is 1.74 times higher than that in the U.S. in 2011 if land is included in capital input, compared to 1.37 times if land were excluded.

The price of a capital input is the product of the price of acquisition of the corresponding asset and the annualization factor that converts the capital stock into a flow of capital services. The final step in measuring PPPs for capital inputs is to determine the relative value of the annualization factors between Japan and the U.S. A novel feature of our data sets for Japan and the U.S. is that the annualization factors are measured on the basis of comparable formulations of the price of capital input, assuming asset-specific revaluations for all assets and endogenous rates of return for each industry. Tax considerations also provide a key component of the prices of capital inputs.[9]

The annualization factors are described in the appendix and estimated for 105 assets and 47 industries in Japan and 106 assets in 61 industries in the U.S., including research and development, land, and inventories as assets. The estimates are aggregated into measures for the 34 assets of the Japan-US common asset classification in each industry. The aggregate PPP for capital inputs is estimated as 1.39 in 2011. The price gap in capital inputs is modest reflecting the lower annualization factors in Japan due to lower rates of return, compared to 1.74 as the aggregate PPP for capital acquisition.

2.5 PPPs for Labor Input

In defining PPPs for labor inputs, we follow Nomura and Samuels (2003). The elementary level PPPs for labor input as of the base year PPP_{LijT} are measured as average hourly labor compensation in each labor group i in industry j, taking one dollar's worth as the unit at the elementary level. The elementary level PPPs for labor input are aggregated to the industry-level, using the translog index in Equation (5) of the Appendix.

For Japanese and U.S. data sets, the labor inputs are cross-classified by gender, age, education, class of worker, and industry. The common labor classification system for Japan and

[9] In measuring capital input in Japan, capital consumption allowances, income allowances and reserves, special depreciation, corporate income tax, business income tax, property taxes, acquisition taxes, debt/equity financing, and personal taxes are taken into account. In the U.S., similar features of the tax code are accounted for in estimating the implicit rental rate of capital.

the U.S. enables us to compare wages of similar workers. After classifying the workers by sex, we allocate the workers by the other categories – industry, age, class of worker, and education. The U.S. data set has eight age classifications for workers and Japan has eleven. We choose a common classification of six age groups – under 24 years old, 25-34, 35-44, 45-54, 55-64, and over 65 years of age. As a common education classification, we choose four education categories – less than high school degree, high school degree, some college, and college degree and above.

In both economies workers are classified as employed or self-employed and unpaid family workers. We consider only employed workers when measuring the PPPs for labor input. After cross-classifying the data by all the demographic characteristics, we have 1680 groups in total. The industry-level PPP for labor inputs are calculated as the translog index of the elementary-level PPPs.

3 Results

3.1 PLIs for Output, Factor Inputs, and Intermediate Inputs

We now turn to the main results of this paper. We estimate purchasing power parities (PPP) for value added at the industry level by a double deflation method. For this purpose, we use industry-level PPPs for gross output and intermediate inputs of energy, materials, and services for the benchmark year 2011. The PPP gross domestic product (GDP) is defined as a translog index of the industry-level PPPs for value added, weighted by average industry shares of value added at current prices in the two countries. Similarly, the PPPs for factor inputs and intermediate inputs by industry are defined as translog indexes of PPPs for these inputs at the elementary level, using average industry shares as weights. Taking estimates of the PPPs for 2011 as a benchmark, we derive time-series estimates of the PPPs by extending the benchmark back to 1955 and forward to 2015, using from time-series data on KLEMS prices for outputs and inputs from the industry productivity (KLEMS) accounts in Japan and the U.S.

Table 1 presents our estimates of PPPs and price level indices (PLIs) for Japan relative to the U.S. The long-term trends of PPPs for output and inputs are shown in Figure 1. The yen-dollar exchange rate is represented as a shadow in Figure 1. If the PPP is higher than the exchange rate, the Japanese price is higher than the U.S. price, U.S. producers are more competitive on the international market. Figure 2 represents the PLIs. Through the mid-1970s the

Japanese price for output (GDP) was lower than the U.S. price.[10] The Japanese prices of inputs of capital, labor, materials, and services were lower than the U.S. prices as well, over this period. The exception is the energy price. The 1.5–3.5 times higher price of energy is a long-lasting disadvantage for Japanese producers in competing with U.S. producers.

Lower input prices, especially the price of labor input (only 16 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.

Table 1 : PPPs and PLIs for Output and KLEMS

	1955	1960	1965	1970	1975	1980	1985	1990	1991	1995	2000	2005	2009	2010	2011	2015
PPPs (Purchasing Power Parities)																
Output (GDP)	176.1	183.6	210.2	223.1	257.0	225.7	191.1	172.3	168.9	155.9	140.5	124.0	114.3	114.3	109.7	109.3
Capital	140.0	207.5	193.2	259.4	202.1	196.6	182.4	177.1	173.7	143.6	145.0	132.1	113.0	118.3	111.3	124.6
Labor	57.4	62.7	96.0	117.4	190.3	168.8	145.3	140.5	144.1	135.3	109.3	87.6	79.4	78.3	76.7	72.3
Energy	589.5	622.7	655.2	629.0	666.9	588.1	508.8	335.8	349.7	318.0	285.4	199.2	201.2	180.0	158.8	219.3
Material	266.7	252.7	257.9	258.5	260.0	224.8	198.7	159.3	161.4	138.2	132.5	115.9	111.1	104.4	97.9	104.3
Service	232.6	223.4	243.8	243.4	292.9	276.6	230.5	206.5	204.3	181.5	158.2	133.5	118.3	115.2	112.1	105.9
ref) GDP-expenditure based	---	170.6	204.1	226.0	266.0	245.6	206.9	189.2	187.8	174.5	155.0	129.6	115.5	111.6	107.5	105.3
Exchange Rate	360.0	360.0	360.0	360.0	296.8	226.8	238.5	144.8	134.5	94.1	107.8	110.2	93.5	87.8	79.8	121.0
PLIs (Price Level Indices)																
Output (GDP)	0.49	0.51	0.58	0.62	0.87	1.00	0.80	1.19	1.26	1.66	1.30	1.13	1.22	1.30	1.37	0.90
Capital	0.39	0.58	0.54	0.72	0.68	0.87	0.76	1.22	1.29	1.53	1.35	1.20	1.21	1.35	1.39	1.03
Labor	0.16	0.17	0.27	0.33	0.64	0.74	0.61	0.97	1.07	1.44	1.01	0.80	0.85	0.89	0.96	0.60
Energy	1.64	1.73	1.82	1.75	2.25	2.59	2.13	2.32	2.60	3.38	2.65	1.81	2.15	2.05	1.99	1.81
Material	0.74	0.70	0.72	0.72	0.88	0.99	0.83	1.10	1.20	1.47	1.23	1.05	1.19	1.19	1.23	0.86
Service	0.65	0.62	0.68	0.68	0.99	1.22	0.97	1.43	1.52	1.93	1.47	1.21	1.26	1.31	1.41	0.87

Sources: Our estimates, except the reference series of the PPP for GDP-expenditure based, which is from Eurostat-OECD (2012). Note: The PPP for GDP-output based is defined as a translog index of industry-level PPPs for value added, which is calculated by the double deflation method. The Price Level Indices are defined as the ratio of PPPs to exchange rate. The PPP and exchange rate are defined by Japanese Yen/ US Dollar.

The end of rapid Japanese economic growth in the beginning of the 1970s provided a turning point towards a decrease in the PPP for capital input, as shown in Figure 1. After the middle 1970s the PPPs for all inputs began to decrease. Japan's prices of output and all inputs

[10] Our estimates of PPP for GDP are based on value added by industry, while the Eurostat-OECD PPPs presented in Table 1 are based on expenditures. In addition, there is a difference in scope, as our estimates include imputations for a return to government-owned capital and a capital service cost of household durables. Although the two PPP estimates are nearly identical in 2009, our output-based estimates are higher through the beginning of the 1970s and lower in the 1990s and 2000s. Again, in the 2010s, our output-based estimates are higher the expenditure-based estimates.

have continued to decline for four decades, relative to prices in the U.S. For two decades Japan has undergone substantial deflation and the yen has continued to appreciate. By 1985, the yen was undervalued by 20 percent, based on our estimate of the PLI for output. After the Plaza Accord of 1985, the rapid strengthening of the yen relative to the U.S. dollar in the late 1980's reversed this relationship, leading to an overvaluation of the yen by 26 percent in 1991. The revaluation of the yen continued through 1995, leading to a huge overvaluation of 66 percent. At that time the price of labor input was 44 percent higher in Japan, which posed a formidable barrier to Japanese products in international markets.

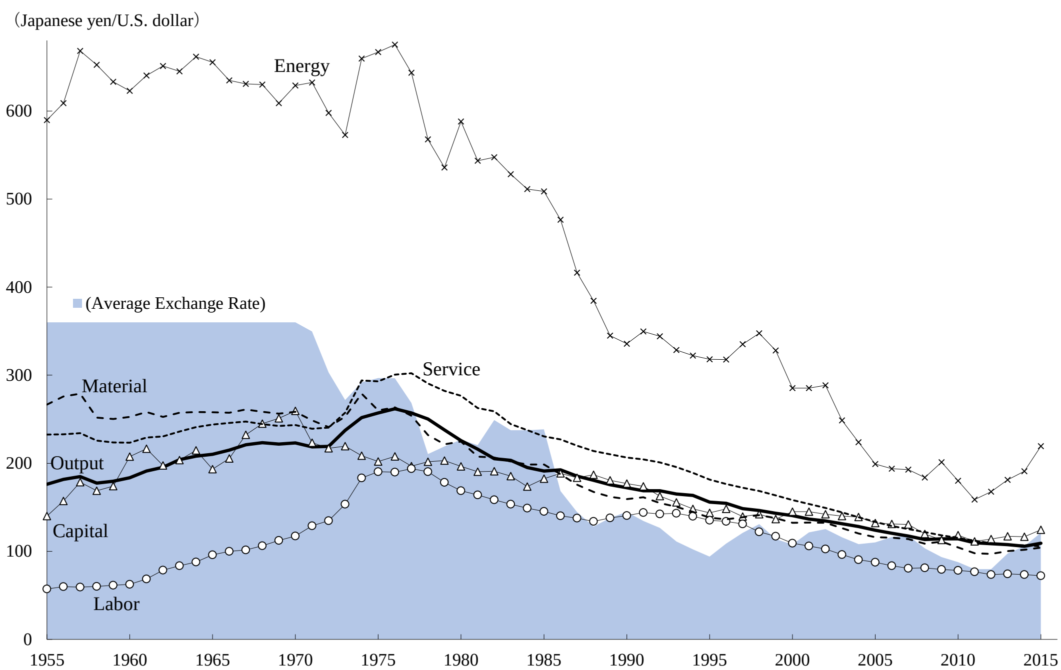

Figure 1 : PPPs for Output and KLEMS, 1955–2015

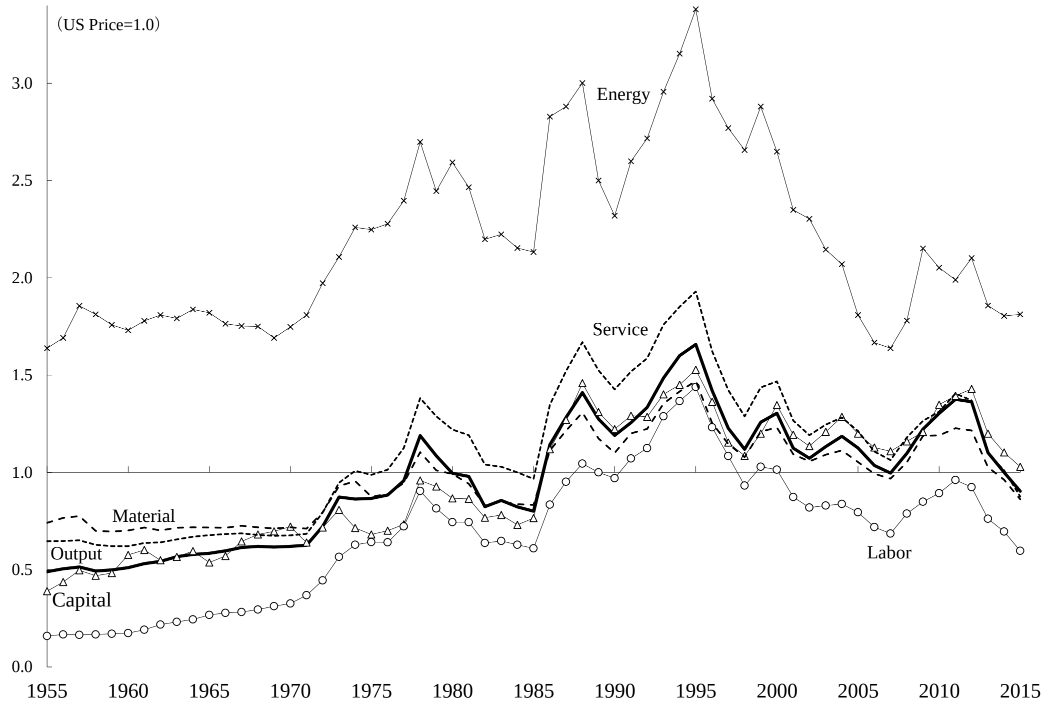

Figure 2 : PLIs for Output and KLEMS, 1955–2015

Japanese policy makers required more than a decade to deal with the overvaluation of the yen that followed the Plaza Accord. This was accomplished primarily through domestic deflation, with a modest devaluation of the yen. The PLI for GDP in Japan, relative to the U.S., declined by 4.2 percent annually through 2007 from the peak attained in 1995. The decline in the PPP for GDP of 2.3 percent per year was the result of modest inflation in the US of 1.7 percent and deflation in Japan of 0.6 percent. In addition, the yen-dollar exchange rate depreciated by 1.9 percent per year.

Although the market exchange rate of the yen approached the PPP for GDP in 2007, the yen appreciated sharply in response to quantitative easing by the Federal Reserve that was taken 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 36 percent higher in Japan. In response to quantitative easing by the Bank of Japan under Governor Haruhiko Kuroda, the yen sharply declined, reaching 121.0 yen per dollar in 2015. This is well below our estimate of the PPP for GDP of 109.3 in 2015 and has restored Japanese international competitiveness.

Figure 3 presents the PLIs for GDP in individual industries in the benchmark year 2011. Industry-level PLIs for gross output reflect the prices of intermediate inputs as well as value added, so that the PLI for value added is a better measure for evaluating the price competitiveness of individual industries. The second panel of Figure 3 gives the contributions of individual industries to the PLI for GDP. The Japanese Wholesale and Retail industry has the largest contribution (6.7 percentage point) to the PLI for GDP at the aggregate level. By contrast, Japan's Medical Care sector in services and Primary Metal and Chemical Products sectors in manufacturing contributed negatively to the PLI for GDP. All three of these industries are highly competitive with their U.S. counterparts.

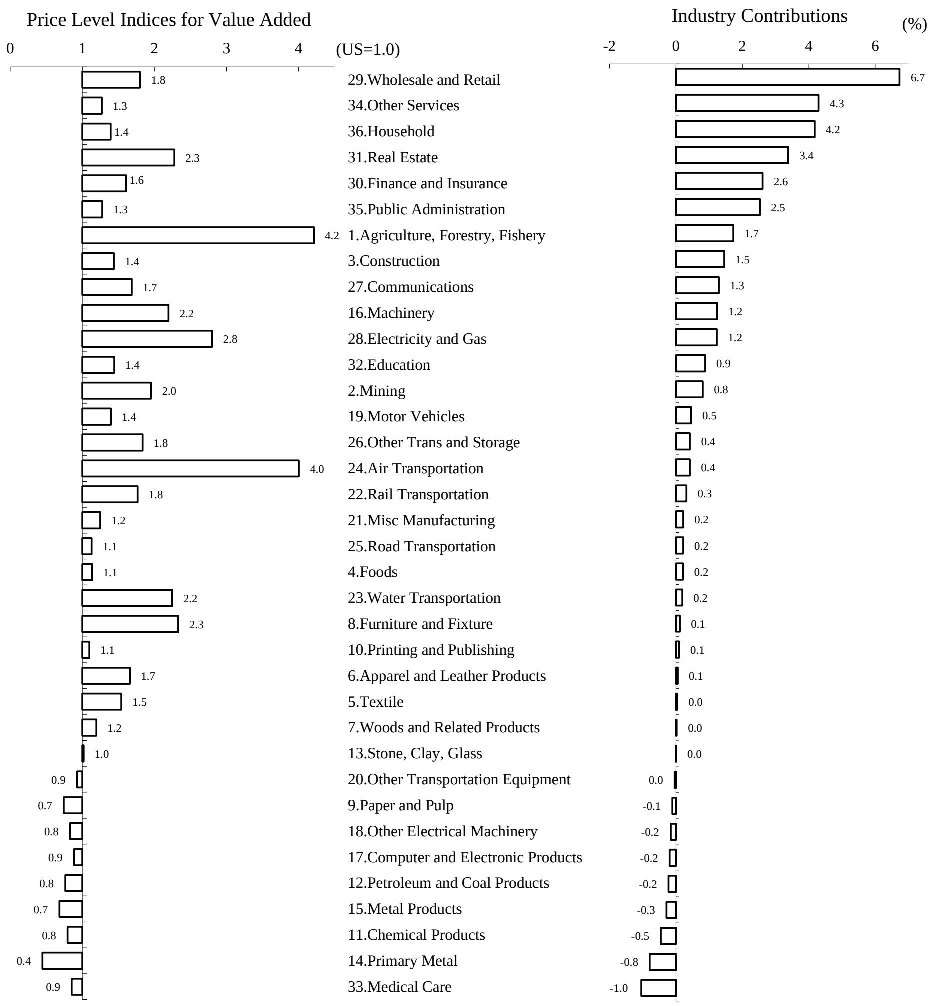

Figure 3 : Industry-level PLIs for GDP, 2011

3.2 VLIs of Output and Inputs and Productivity Level Indices

Table 2 summarizes the productivity gaps between Japan and the U.S. This table compares volume level indices (VLI) of output, output per capita, input per capita, and total factor productivity (TFP) between the two countries over the period 1955–2015. Differences in output per capita can be decomposed into differences in input per capita and differences in TFP, as defined in Equation (11) in the Appendix. For example, Japanese GDP was 27 percent of the U.S. level in 2015. GDP per capita in Japan was 68 percent of the U.S. level, while Japanese input per capita was 78 percent and Japanese TFP was 87 percent.

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

	1955	1960	1965	1970	1975	1980	1985	1990	1991	1995	2000	2005	2009	2010	2011	2015
Output	0.10	0.15	0.21	0.31	0.35	0.37	0.39	0.42	0.44	0.41	0.35	0.31	0.28	0.29	0.28	0.27
Output per Capita	0.19	0.30	0.40	0.60	0.67	0.72	0.77	0.86	0.90	0.86	0.77	0.72	0.68	0.69	0.68	0.68
Input per Capita	0.38	0.47	0.63	0.78	0.88	0.88	0.89	0.93	0.95	0.95	0.85	0.82	0.81	0.82	0.81	0.78
Capital Input per Capita	0.23	0.28	0.43	0.58	0.72	0.76	0.76	0.83	0.87	0.88	0.77	0.69	0.65	0.65	0.64	0.62
Capital Stock per Capita	0.40	0.47	0.62	0.76	0.90	0.98	1.01	1.05	1.08	1.14	1.15	1.13	1.12	1.12	1.11	1.09
Capital Quality	0.57	0.59	0.70	0.76	0.80	0.77	0.75	0.79	0.81	0.77	0.67	0.61	0.58	0.58	0.58	0.57
Labor Input per Capita	0.63	0.82	0.90	1.03	1.04	1.03	1.05	1.05	1.06	1.04	0.97	1.00	1.03	1.04	1.02	0.99
Hours Worked per Capita	1.05	1.29	1.31	1.39	1.29	1.22	1.21	1.17	1.19	1.15	1.04	1.06	1.09	1.10	1.09	1.05
Labor Quality	0.60	0.64	0.69	0.74	0.81	0.85	0.87	0.90	0.89	0.91	0.92	0.94	0.94	0.94	0.94	0.94
TFP	0.51	0.63	0.65	0.77	0.77	0.82	0.86	0.92	0.95	0.91	0.90	0.87	0.83	0.85	0.85	0.87
Average Labor Productivity	0.18	0.23	0.31	0.44	0.52	0.59	0.63	0.73	0.76	0.75	0.74	0.68	0.62	0.63	0.63	0.65
Average Capital Productivity	0.85	1.07	0.93	1.04	0.93	0.95	1.00	1.03	1.03	0.98	1.00	1.04	1.04	1.07	1.06	1.09

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

Differences in input per capita in Table 2 result from differences in capital and labor input. In 1955 Japanese labor input per capita was 63 percent of the U.S. level in 1955. The gap of 37 percent was the result of the lower quality of labor in Japan, reaching only 60 percent of the U.S. level. After 1970 the lower quality of Japanese labor was largely offset by longer hours worked per capita, 39 percent longer in 1970. Subsequently, Japan has reduced hours worked per capita and improved labor quality, reducing the gap in labor quality to 6 percent by the mid-2000s.

Japanese capital input presents a striking contrast to labor input in that the level still remains significantly below the U.S. In 1955 Japanese capital input per capita was only 23 percent of the U.S. level, but rapidly rising levels of investment in Japan during the period 1955–1975 reduced the gap to 28 percent by 1975. The gap continued to close through 1995, when Japanese capital input per capita reached 88 percent of the U.S. level. The investment slump that followed the collapse of the bubble economy in Japan and the U.S. investment boom of the late 1990s widened the gap to 23 percent in 2000 and 38 percent in 2015. This accounts for most of the remaining gap in input per capita of 22 percent in 2015. A large gap in capital input per capita is due to lower quality in Japan's capital. In Equation (9) of the Appendix, capital quality is defined as capital input per unit of capital stock. Lower quality reflects the Japan's larger share of land as capital, i.e., 41.8 percent of total capital stock at current prices in 2011, compared to 14.0 percent in the U.S., and lower annualization factors of land compared to other assets. Japanese capital quality, relative to the U.S., was 57 percent in 1955. This rose to 81 percent by 1991, but declined to 57 percent of the U.S. level again in 2015.

Our estimate of the Japan-U.S. gap for total factor productivity (TFP) in 1955 is 51 percent. This gradually declined over the following 36 years and reached a low of 5 percent in 1991, as shown in Figure 4. Economic growth and its sources in for each of Japanese and the U.S. economies are summarized in Table 3. The growth rate of TFP in Japan was 3.1 percent and 1.3 percent per year during 1955–1971 and 1971–1991, respectively. After 1991 this declined to –0.3, slightly negative, until 2009. By comparison the growth rate of TFP in the U.S. has been stable as 0.4 per year for the period 1991–2009. As a result, the bilateral TFP gap has expanded to 17 percent in 2009. From 2009 to 2015, the gap shrank to 13 percent in 2015, reflecting TFP growth of 1.2 and 0.5 in Japan and the U.S., respectively. There is still an ample productivity gap between the two countries.

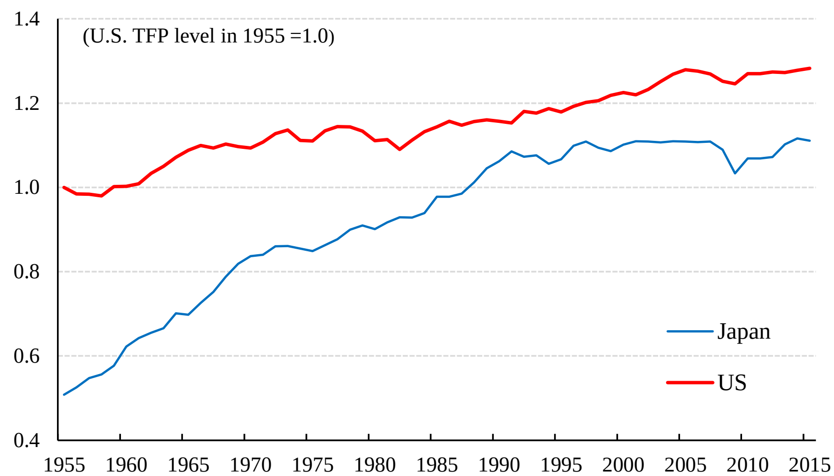

Figure 4 : Japan-US TFP Level Indices, 1955–2015

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	2010-15	1955-71	1971-91	91-2009	2009-15
								Japan								
Output	10.2	10.7	11.6	5.2	4.7	4.3	5.1	1.8	1.3	0.7	-0.6	0.9	10.6	4.7	0.4	1.3
Capital Input	3.5	6.8	6.0	4.4	2.1	1.6	2.6	1.6	0.8	0.5	0.2	0.1	5.5	2.5	0.7	0.0
IT Capital	0.1	0.2	0.2	0.2	0.1	0.2	0.4	0.2	0.4	0.5	0.2	0.1	0.2	0.2	0.3	0.1
(of which quality)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Non-IT Capital	3.4	6.7	5.8	4.1	1.9	1.4	2.2	1.4	0.4	0.0	0.0	0.0	5.3	2.3	0.4	-0.1
(of which quality)	0.8	2.2	1.5	1.1	0.2	0.3	1.1	0.4	-0.2	-0.2	-0.2	0.0	1.5	0.6	-0.1	-0.1
Labor Input	2.6	1.6	1.9	0.6	1.4	1.0	0.9	0.1	-0.1	0.1	0.0	0.1	2.0	0.9	0.0	0.1
(of which quality)	0.9	1.0	0.7	1.0	0.8	0.6	0.5	0.3	0.4	0.4	0.3	0.2	0.9	0.7	0.4	0.2
TFP	4.1	2.3	3.6	0.3	1.2	1.6	1.7	0.1	0.6	0.1	-0.7	0.8	3.1	1.3	-0.3	1.2
Agriculture	0.5	-0.1	-0.3	0.0	-0.1	0.1	0.0	-0.1	0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
IT-manufacturing	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.1	0.4	0.3	0.1	0.1	0.1	0.2	0.2	0.1
Motor Vehicle	0.2	0.0	0.2	0.1	0.2	0.0	0.1	0.0	0.0	0.1	-0.1	0.1	0.1	0.1	0.0	0.1
Other manufacturing	1.5	1.6	2.1	0.0	0.7	0.7	0.3	-0.1	0.1	0.1	-0.3	0.0	1.6	0.4	-0.2	0.3
Commonucations	0.2	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Trade	0.7	0.9	0.9	0.1	0.7	0.0	0.8	0.7	0.1	0.2	-0.3	0.3	0.8	0.5	0.1	0.3
Finance & Insurance	0.0	0.2	0.2	0.1	0.2	0.1	0.3	0.0	0.0	-0.1	-0.2	0.1	0.2	0.2	-0.1	0.0
Other services	1.0	-0.6	0.5	-0.3	-0.7	0.6	-0.2	-0.6	-0.2	-0.5	0.0	0.2	0.2	-0.1	-0.4	0.3
								United States								
Output	2.4	4.9	3.6	2.7	3.4	3.3	3.4	2.6	4.5	2.9	1.0	2.2	3.6	3.1	2.9	2.2
Capital Input	2.1	2.3	2.8	2.1	2.0	1.8	2.0	1.5	2.5	1.9	1.1	0.9	2.4	1.9	1.9	0.8
IT Capital	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.5	1.1	0.6	0.4	0.2	0.1	0.4	0.7	0.2
(of which quality)	-0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.2	0.3	0.1	0.1	0.1	0.0	0.1	0.2	0.1
Non-IT Capital	2.0	2.2	2.6	1.9	1.7	1.4	1.5	1.0	1.5	1.3	0.8	0.7	2.3	1.6	1.2	0.6
(of which quality)	0.7	0.3	0.5	0.6	0.5	0.4	0.6	0.4	0.6	0.7	0.2	0.1	0.5	0.5	0.5	0.0
Labor Input	0.3	1.0	0.7	0.3	1.4	0.9	1.2	0.7	1.2	0.2	0.0	1.1	0.6	0.9	0.6	0.9
(of which quality)	0.3	0.3	0.0	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2
TFP	0.0	1.6	0.1	0.3	0.0	0.6	0.2	0.4	0.8	0.9	-0.1	0.2	0.6	0.2	0.4	0.5
Agriculture	0.1	0.1	0.1	0.1	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0
IT-manufacturing	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.5	0.2	0.2	0.0	0.0	0.2	0.3	0.1
Motor Vehicle	-0.1	0.1	-0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Other manufacturing	-0.1	0.6	0.2	0.0	0.0	0.3	0.1	0.0	0.0	0.2	0.0	-0.1	0.2	0.0	0.1	-0.1
Commonucations	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Trade	0.1	0.3	0.1	0.3	0.0	0.3	0.1	0.2	0.5	0.2	-0.2	0.1	0.2	0.2	0.2	0.1
Finance & Insurance	0.0	-0.1	-0.1	-0.1	0.1	-0.1	-0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Other services	0.1	0.5	-0.1	-0.1	-0.2	-0.3	-0.2	-0.2	-0.4	-0.1	-0.1	0.2	0.1	-0.2	-0.2	0.4

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

Table 2 also provides level indices for labor and capital productivity, defined as output per hour worked and output per unit of capital stock, respectively. Labor productivity in Japan was only 18 percent of the U.S. level in 1955. The labor productivity gap closed rapidly until 1991, when Japanese labor productivity reached 76 percent of the U.S. level. The trends in labor and capital productivity reflect relative factor supplies in the two economies. Japan has had a substantially higher labor/capital ratio than the U.S. throughout the period. This is consistent with the lower capital/labor PPPs presented in Table 1.

The sources of the Japan-US gap in labor productivity are shown in Figure 5. In 1955 lower capital deepening in Japan accounted for 49 percent of the Japan-US labor productivity gap, while lower Japanese TFP and lower quality of labor input explained 36 percent and 15 percent, respectively. In 2015 lower TFP still explains 34 percent of the labor productivity gap, while capital deepening accounts for 55 percent. Figure 6 presents the sources of the Japan- U.S. gap in capital productivity. Over the whole observation period, the gap in capital productivity was relatively small, with capital deepening mostly counterbalanced by the gaps in TFP and capital quality.

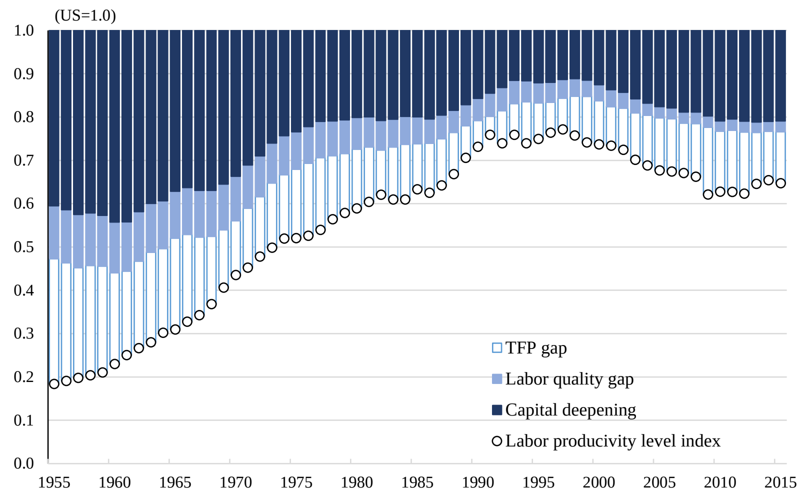

Figure 5 : Sources of Japan-U.S. Gap in Labor Productivity Level Index, 1955–2015

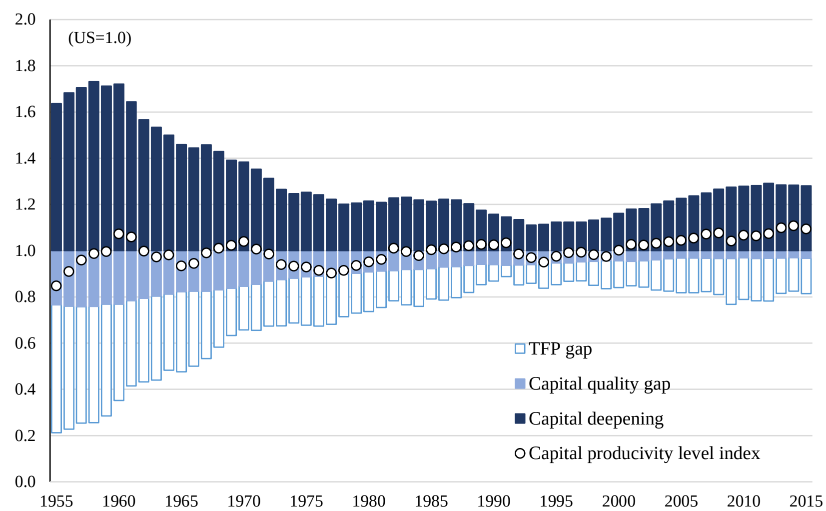

Figure 6 : Sources of Japan-U.S. Gap in Capital Productivity Level Index, 1955–2015

3.3 Industry Origins of Japan-U.S. TFP Gap

Figure 7 presents the Japan-U.S. gap in total factor productivity (TFP) decomposed into manufacturing and non-manufacturing sectors for the period 1955–2015. In 1955 both gaps were very large. The TFP gap for manufacturing disappeared by 1980 and the overall TFP gap reflected the lower TFP in non-manufacturing. Japanese manufacturing productivity relative to the U.S. peaked 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 11 percent, but expanded to reach 16 percent in 2009. The TFP gap in non-manufacturing remained almost changed and was 14 percent in 2015.

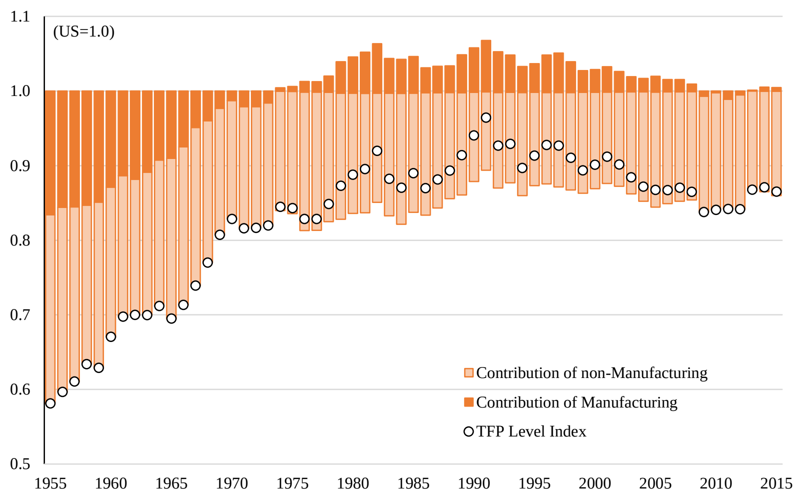

Figure 7 : TFP Gaps in Manufacturing and Non-Manufacturing, 1955–2015

Figures 8–11 presents industry-level TFP gap for Japan and the U.S. in the first panel and the contributions of each industry to the overall TFP gap for the two countries in the second panel, for the periods 1955, 1971, 1991, and 2015. Industries are ordered by their contributions to the TFP gap. The contribution of each industry to the aggregate TFP gap uses Domar weights from Equation (13) of the Appendix. 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 1955, TFP levels are lower by more than 30 percent compared to the U.S. in 18 industries in our study. This number decreased to 7 in 1971 and to 4 in 1991, indicating catching up at the industry level. In 1991, in which the Japan-U.S. TFP gap was the smallest in our whole observation period, the number of the industries with a higher TFP exceeds that of the industries with a lower TFP. In 2015, Japanese TFP exceeded that in the U.S. for 11 of 36 industries, led by Medical Care and manufacturing sectors of Metal Products, Primary Metal, and Chemical Products. These industries made a contribution to Japanese TFP, relative to the U.S., from 0.6 to 0.8 percentage points. Domestically oriented industries except Medical Care, such as Wholesale and Retail Trade, Other Services, Real Estate, Agriculture, Forestry, and Fishery, and Finance and Insurance have much lower productivity levels than their U.S. counterparts and made negative contributions to the overall TFP gap totaling 13 percentage points in 2015.

The Agriculture, Forestry, and Fishery industry has a TFP level that 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 scale of agricultural enterprises or differences in the fertility of land in 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. In addition, the productivity differences can be traced to the fact that workers over 65 years of age make up 51 percent of the agricultural labor force in Japan, compared with 10 percent of the non-agricultural labor force in 2015, based on our labor data. Although a large share of elderly workers is expected to be captured as a lower quality of labor input, some properties of lower quality are reflected in the TFP gap as well.

Although Other Electrical Machinery and Computer and Electronic Products in Japan had slightly higher levels of TFP than their U.S. counterparts in 2015, the TFP advantage almost disappeared in Motor Vehicles, in which two-thirds of the vehicles of Japanese vendors are produced in overseas (including the U.S.) at present. However, manufacturing sectors that produce industrial materials, such as Metal Products, Primary Metal, and Chemical Products have higher levels of TFP relative to their U.S. counterparts. Since the 1970s, these industries have been concentrating their resources on higher value-added products that require more advanced technologies. We conclude that Japan’s highly competitive manufacturing industries should be able to find new opportunities in both international and domestic markets under the exchange rate policies of the Bank of Japan. Efforts to improve Japanese productivity should focus on industries in trade and services that are protected from international competition. Agriculture, Forestry, and Fishery is a special case that will require structural reform, followed by opening to trade.

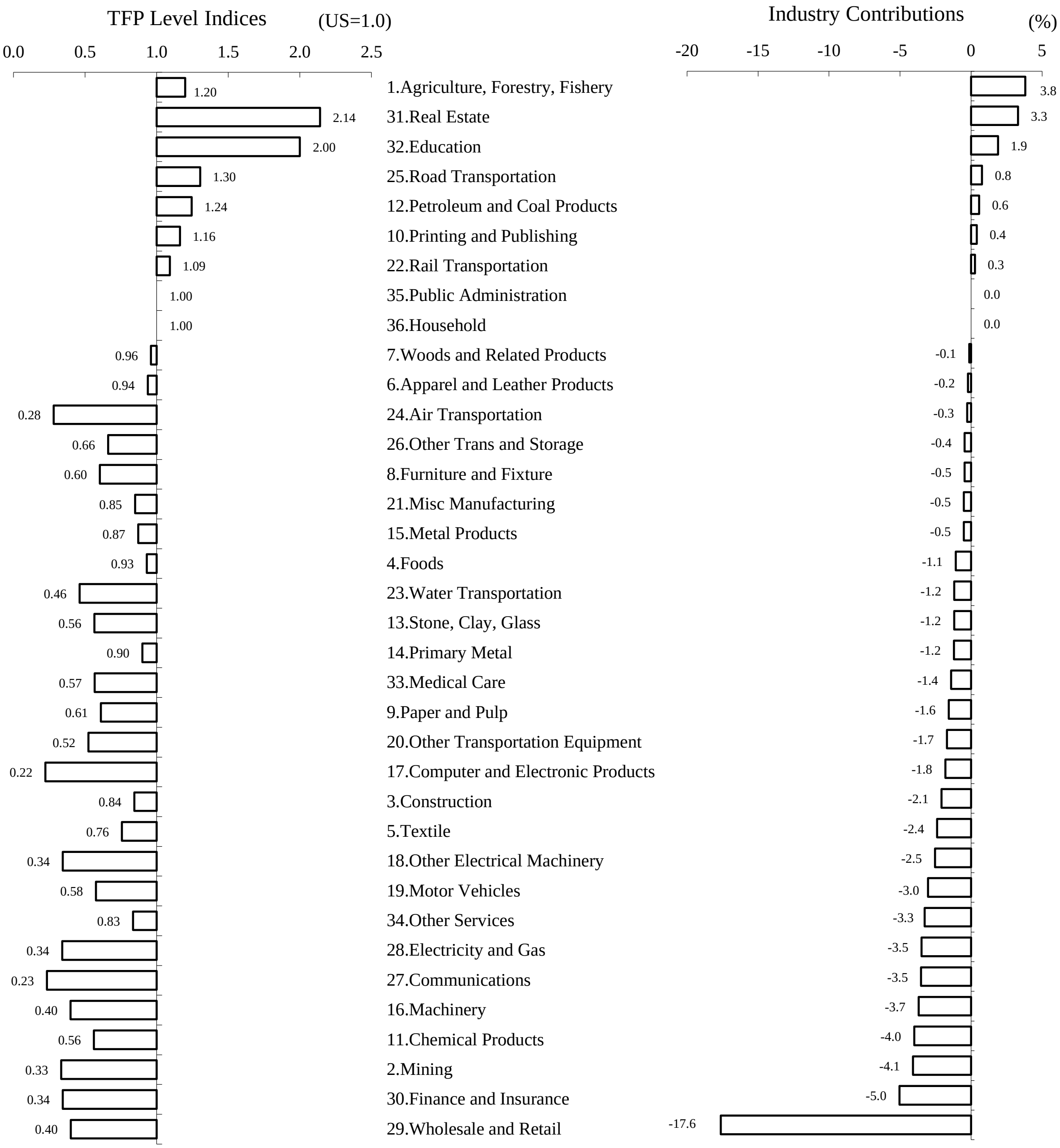

Figure 8: Industry Origins of TFP Gap, 1955

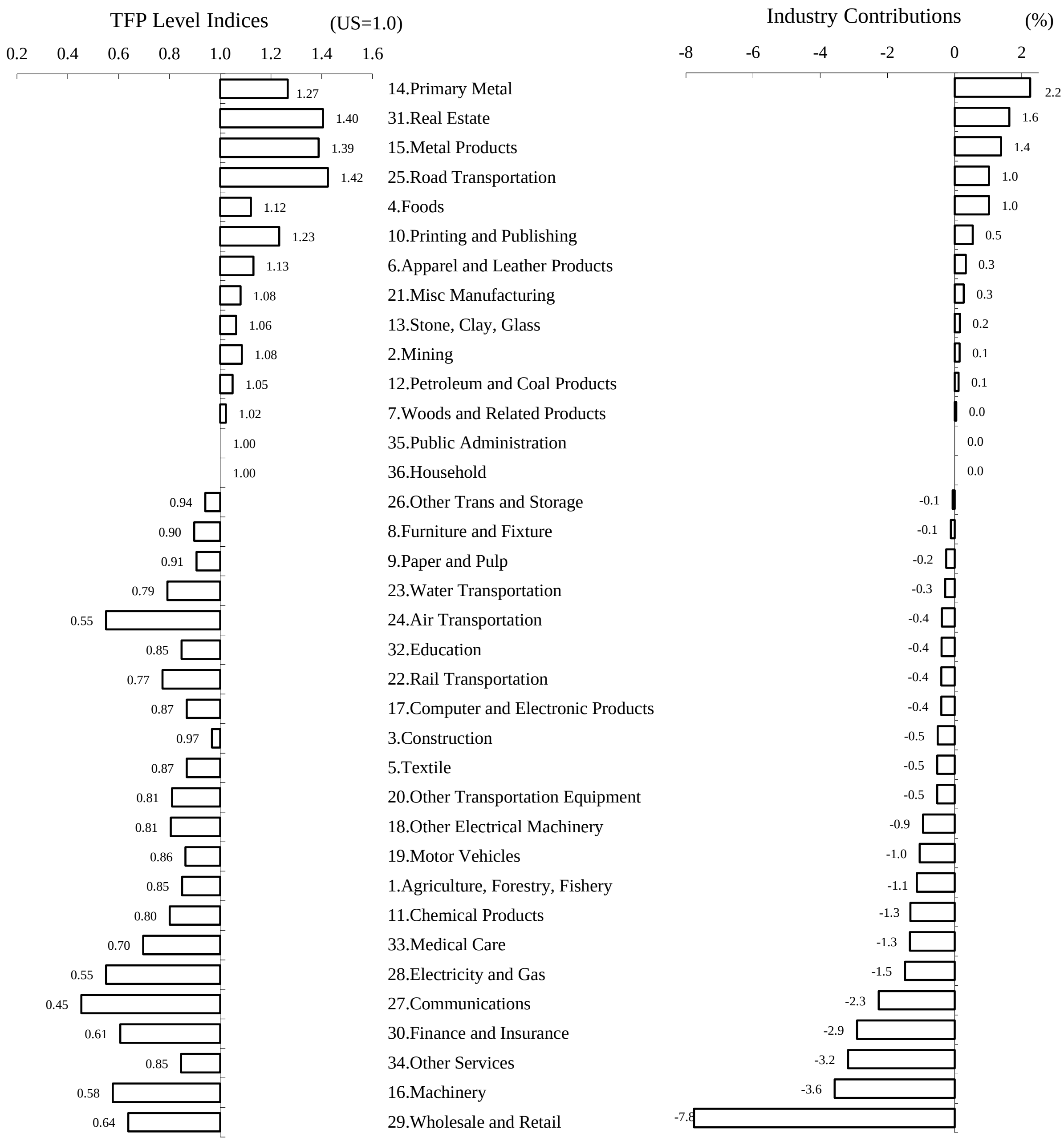

Figure 9: Industry Origins of TFP Gap, 1971

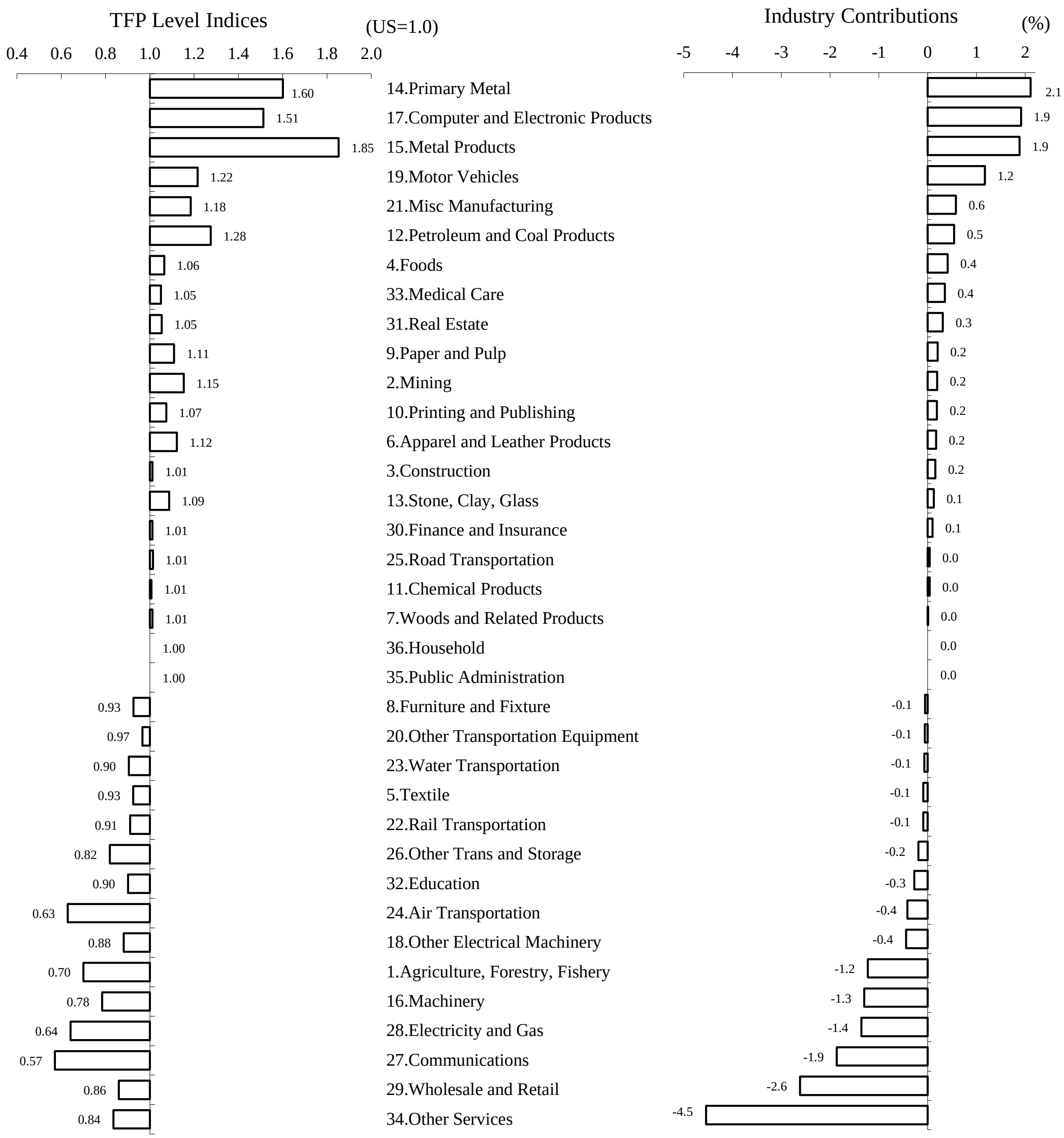

Figure 10: Industry Origins of TFP Gap, 1991

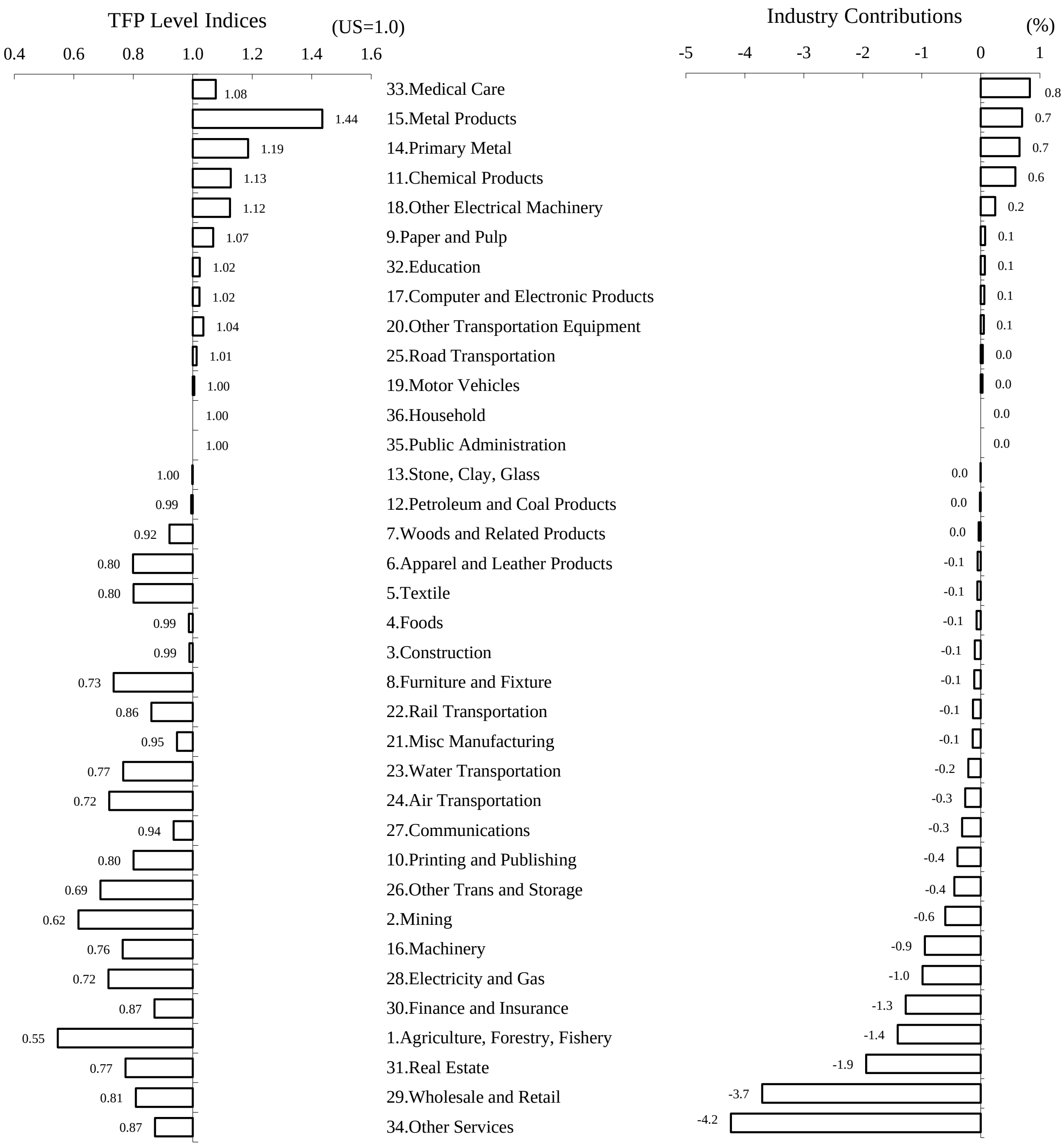

Figure 11: Industry Origins of TFP Gap, 2015

Figure 12 represents long-term trends in TFP levels in Japan and the U.S. for twelve industries that are particularly important in accounting for the productivity differences between the two countries. Productivity levels in each industry are normalized such that the U.S. productivity level in 1955 equals unity. In 1955 the TFP level in Japan's Agriculture, Forestry, and Fishery industry was slightly over that of the U.S., but the TFP gap reversed dramatically after 1973, reflecting differences in the scale of individual production units, as well as massive public investments in new agricultural technology in the U.S.[11] Construction showed declining productivity trends in both economies. We find an acceleration of the decline in Japan after the collapse of the "bubble economy" in Japan at the beginning of the 1990s, but productivity growth has recently recovered in Japan.

The U.S. started with an early lead in Chemical Products, but the Japanese industry achieved parity by the late 1980s. Relative productivity levels have been very similar over the following three decades with Japan emerging with a slight lead recently. Computer and Electronic Products is the IT-producing sector. The Japanese industry has led its U.S. counterpart since the mid-1970s. The U.S. rate of productivity growth accelerated sharply during the IT investment boom of the late 1990s [12] and the U.S. leads in productivity since the late 2000s. In Other Electrical Machinery, the U.S. started with an early lead but the Japanese industry achieved parity in the early 2000s.

The Japanese Motor Vehicles industry has led its U.S. counterpart since the early 1980s. Although the TFP gap has been constant since the 1980s, the growth of TFP in the U.S. industry has revived dramatically after the financial and economic crisis of 2007–2009. The Japanese Communications industry first achieved parity with the U.S. industry in the early 2000s, when a policy of competition was implemented in Japan's communications market. This parity disappeared in the mid-2000s, due to a decline of TFP in Japan and an improvement in the U.S. industry, but they are getting close again due to the opposite changes in the early 2010s.

Wholesale and Retail Trade has contributed to the relatively higher TFP in the U.S. since 1955. Some studies like Kuribayashi (1991) and Goldman (1992) pointed out the inefficiencies of the Japanese distribution system, such as the large number of small retail outlets due to the Large-scale Retail Stores Law, a multilayered nature with secondary and tertiary wholesalers, the sale-or-return system, or cultural inertia, especially from the middle of the 1980s. Although the Large-Scale Retail Stores Law was abolished in 2000, the TFP gap has widened since the late 1990s in our study, due to a slump in TFP growth in Japan and an acceleration of TFP growth in

[11] Alston (2018) describes the importance of organized R&D in agricultural productivity growth in the U.S.
[12] The acceleration in U.S. productivity growth in IT-production and subsequent deceleration is discussed by Jorgenson, Ho, and Samuels (2015).

the U.S. In Medical Care the Japan's TFP level has been almost stable since the mid-1970s, the U.S. TFP has declined steadily for two decades since the same period. As a result, a considerable gap was generated in the late 1990s that has sustained to date. Other Services has undergone a steady modest decline in TFP in both economies, but the U.S. lead is gradually diminishing.

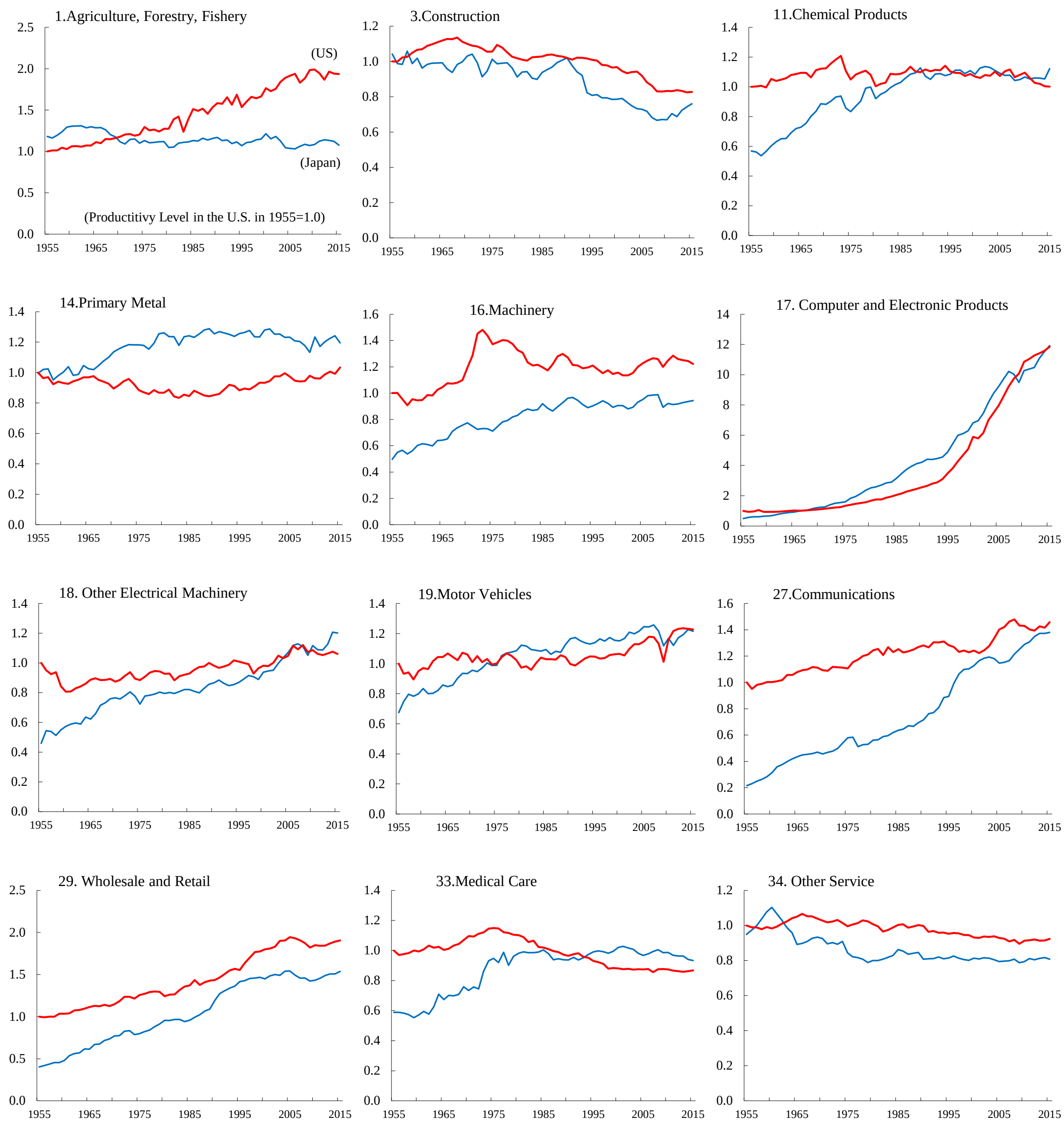

Figure 12: TFP Level Indices in Selected Industries, 1955–2015

4 Conclusion

In this paper we have analyzed trans-pacific competition between Japan and the U.S. over more than half a century. This has been feasible due to the high quality of economic statistics in both countries, the result of decades of effort by many economic statisticians. Price level indices enable us to summarize international competitiveness of Japanese and U.S. industries at different points of time very succinctly. These indices incorporate purchasing power parities between the two countries as well as the market exchange rate of the Japanese yen versus the U.S. dollar.

Variations in the yen-dollar exchange rate have resulted in substantial fluctuations in international competitiveness between Japan and the U.S. over the period 1955–2015. During the first half of this period, ending with the Plaza Accord of 1985, the yen was under-valued relative to the dollar and many Japanese industries involved in international markets became competitive with their U.S. counterparts. This provided an opportunity for Japan to grow rapidly through mobilization of its high quality labor force, high rates of capital formation, and improvements in productivity.

Although the period of double-digit growth in Japan ended with the first oil shock of 1973, the Japanese economy continued to grow more rapidly than the U.S. until the collapse of the "bubble economy" in Japan in the early 1990s. The over-valuation of the yen relative to the dollar after the Plaza Accord reached a peak in 1995 and led to a drastic decline in the international competitiveness of Japanese industries. This precipitated a decline in Japanese exports and a slowdown in economic growth. The slowdown began as a Lost Decade and has now stretched into more than two decades, marked by a much lower rate of capital formation, much slower growth in labor input, and the disappearance of productivity growth.

Price level indices for Japan and the U.S. have real counterparts in the productivity gaps between the two countries. In 1955, almost immediately after Japan recovered sovereignty in 1952, the productivity gap between Japan and U.S. was about fifty percent. This gap closed gradually for more than three decades and Japan nearly achieved parity with the U.S. in 1991. Over the following two decades productivity growth in Japan languished, while U.S. productivity growth slightly accelerated. The Japan-US productivity gap reversed course and has now reached levels that prevailed during the early 1980s.

A major contribution of this paper is to trace the Japan-US productivity gap to its sources at the level of individual industries. Productivity gaps for Japanese and U.S. manufacturing industries, especially those involved in materials processing rather than assembly, are relatively small. The Japanese Motor Vehicles industry has had a higher level of productivity that its U.S. counterpart since the 1970s, but the productivity gap has almost closed after the drastic re-organization of the U.S. industry in the aftermath of the U.S. financial and economic crisis of 2007–2009.

Two industries stand out as opportunities for improvements in productivity. Medical Care in Japan has had a stable level of productivity since the mid-1970s, while the Medical Care industry in the United States has had consistently declining productivity. No doubt substantial improvements are possible in the measurement of outputs in the Japanese and U.S. Medical Care industries. However, our conclusion about declining U.S. productivity is unlikely to be affected. Resumption in productivity growth in Medical Care in the U.S. appears to be feasible and would help to relieve much of the budgetary pressure from rapidly growing cost of health care benefits at every level of the U.S. government.

The Japanese Agriculture, Forestry, and Fishery industry has had very little productivity growth since the mid-1970s, while its U.S. counterpart has achieved consistent and relatively high rates of productivity growth. This industry has been targeted by the Abe Administration as a potential opportunity for rapid productivity growth in Japan. This will require major institutional reform, beginning with the Japanese system of agricultural co-operatives. These co-operatives have added enormously to the costs of agricultural production and distribution in Japan and have undermined growth in Japanese standards of living. A reformed agricultural industry could participate more competitively in international trade.

The final opportunity for Japan is the five industries that are largely insulated from international competition –Electricity and Gas, Real Estate, Wholesale and Retail Trade, Finance and Insurance, and Other Services. Some of these industries are largely insulated from domestic competition through government regulation of pricing and entry. The Abe Administration has already directed attention to the Electric and Gas utilities. Large opportunities remain to improve productivity by removing the barriers to entry in the remaining four industries and eliminating regulations the limit price competition.

We conclude that a half century of trans-pacific competition has produced enormous benefits for Japan and the U.S. However, the two Lost Decades in Japan and the financial and economic crisis that began in the United States in 2007–2009 have created important new opportunities. The progress on measuring the industry origins of the price and productivity gaps that we have reported in this paper provides an important input to focus economic policy in the most effective areas.

A Appendix

A.1 Elementary Level PLIs

We begin with definitions of value, price, and volume for output Y and capital (K), labor (L), energy (E), materials (M), and services (S) inputs at the elementary level. The nominal value $V_{\theta ijtc}$ of industry j in country c (Japan and the U.S.) is defined as follows:

(1) $V_{\theta ijtc} = P_{\theta ijtc} X_{\theta ijtc}$,

where $P_{\theta ijtc}$ is the constant-quality price index and $X_{\theta ijtc}$ is the volume evaluated in each national currency unit. The suffix i represents a subscript for the elementary components in each category θ. For example, the subscript i stands for the elementary level labor input, cross-classified by gender, education, and age. Although the components are different for each θ, we use the same subscript for simplicity.[13] The elementary components i are identical in Japan and the U.S. for our comparisons of the two economies.

For level comparisons we set the unit price $P_{\theta ijTc}$ in the base year T as the unit price in each national currency unit. For example, if the U.S. is the base economy and a "dollar's worth" is the volume unit, the price in the U.S. is one dollar and the price in Japan is the price of the same volume in yen, say, 150 yen. This volume provides the physical unit for each component of i for both economies.

[13] As described in Section 2, the number of elementary components defined for Japan and the U.S., is 33 types of assets for capital inputs (K), 1680 types of labor for labor inputs (L), and 173 products for output (Y), and 174 products for intermediate inputs of energy (E), materials (M), and services (S).

The time series of $P_{\theta ijtc}$ in Equation (1) is set to $P_{\theta ijTc}$ in the base year T. We define the purchasing power parity in the base year as the ratio of $P_{\theta ijTc}$ between Japan and the U.S.,

(2) $PPP_{\theta ijT} = P_{\theta ijTJ} / P_{\theta ijTU}$,

as the purchasing power parity (PPP) at the elementary level. The PPP can be interpreted as the relative cost of purchasing a dollar's worth in each economy.

We define the Japan-US price level index (PLI) as the ratio of the PPP to the market exchange rate of the yen to the dollar. In the base year T,

(3) $PLI_{\theta ijT} = PPP_{\theta ijT}/e_T$,

where e_T is the exchange rate in year *T.* If the exchange rate is 100 yen per dollar and the PPP is 150 yen per dollar, the price level index between Japan and the U.S. is 1.5. While the PPP is independent of the exchange rate, the price level index depends on it. In our example, the price in Japan is higher than the price in the U.S.

The volume measure $X_{\theta ijtc}$ defined as $V_{\theta ijtc}/P_{\theta ijtc}$, provides comparable measures of the quantities purchased in Japan and the U.S. Thus the Japan-US volume level index (VLI) can be defined as:

(4) $VLI_{\theta ijt} = X_{\theta ijtJ}/X_{\theta ijtU}$.

The volume level indices are independent of the exchange rate.

A.2 Industry Level Aggregation

To estimate comparable measures between the two economies at the industry level, we define the industry-level PPP in each category θ as of the base year T as a translog index of the elementary-level PPPs:

(5) $ln\ PPP_{\theta jT} = \Sigma_i\, w_{\theta ijT}\ ln\ PPP_{\theta ijT}$,

where the weights $w_{\theta ijT}$ are the two-country average shares of the elementary components in the current value for each category.

We define the value $V_{\theta jtc}$ in industry j as the sum of the values of elementary components in each category and decompose the industry-level price and volume in two ways:

(6) $V_{\theta jtc} = \Sigma_i P_{\theta ijtc}\, X_{\theta ijtc} = P_{\theta jtc}\, X_{\theta jtc} = P^*_{\theta jtc}\, X^*_{\theta jtc}$

where $X^*_{\theta jtc}$ is a simple sum of the volumes of elementary components ($\Sigma_i X_{\theta ijtc}$) and $X_{\theta jtc}$ is defined as the industry-level translog index of these volumes:

(7) $\Delta ln\, X_{\theta jtc} = \Sigma_i v_{\theta ijtc}\, \Delta ln\, X_{\theta ijtc}$,

where the weights $v_{\theta ijtc}$ are the two-period average shares of the elementary components in the current value in each economy. The two volume measures as of the base year in Japan are rescaled using the industry-level PPPs in Equation (5),

(8) $X_{\theta jTJ} = X^*_{\theta jTJ} = V_{\theta jTJ}/PPP_{\theta jT,}$

to be comparable between Japan and the U.S. The corresponding prices $P_{\theta jtJ}$ and $P^*_{\theta jtJ}$ in Equation (6) are defined as the implicit price indices by $V_{\theta jtc}/X_{\theta jtc}$ and $V_{\theta jtc}/X^*_{\theta jtc}$, respectively ($P_{\theta jTJ} = P^*_{\theta jTJ} = PPP_{\theta jT}$ in the base year T).

The translog volume measure $X_{\theta jtc}$ captures the changes in the components with different marginal products in each category. For example, the substitution towards assets with relatively high service prices and high marginal products, for example, information technology equipment, is reflected as the growth of translog volume measure of capital, not in the simple sum volume measure $X^*_{\theta jtc}$. We define the quality indices of the volume and price in each category θ as:

(9) $Q_{\theta jtc} = X_{\theta jtc} / X^*_{\theta jtc} = P^*_{\theta jtc} / P_{\theta jtc}$.

The time-series PPPs and PLIs for each category are measured by industry, using the implicit translog price index,

(10) $PPP_{\theta jt} = P_{\theta jtJ} / P_{\theta jtU}$ and $PLI_{\theta jt} = PPP_{\theta jt}/e_t$.

The two volume level indices and the quality level indices (QLI) are defined as,

(11) $VLI_{\theta jt} = X_{\theta jtJ} / X_{\theta jtU}$, $VLI^*_{\theta jt} = X^*_{\theta jtJ} / X^*_{\theta jtU}$, and $QLI_{\theta jt} = Q_{\theta jtJ} / Q_{\theta jtU}$,

where $VLI_{\theta jt} = VLI^*_{\theta jt}\, QLI_{\theta jt}$.

For example, the volume level index of capital input can be decomposed to the volume level index of capital stock, $VLI^*_{\theta jt}$, and the quality level index of capital, $QLI_{\theta jt}$. The relative measure of values at the U.S. prices between Japan and the U.S., using the exchange rates, are decomposed to the price level index $PLI_{\theta jt}$, and the volume level index $VLI_{\theta jt}$.

A.3 Productivity Level Indices

Under the assumptions of constant returns to scale and competitive markets in both economies, the productivity gap between Japan and the U.S. is defined as a translog index:

(12) $\ln TLI_{jt} = (\ln VLI_{Yjt} - \Sigma_{\theta} w_{\theta jt} \ln VLI_{\theta jt}) = (\Sigma_{\theta} w_{\theta jt} \ln PLI_{\theta jt} - \ln PLI_{Yjt}),$

where θ includes the intermediate inputs and factor services. The weights $w_{\theta jt}$ are the average, two-country shares of these inputs in the values of output, which are equal to the values of all inputs. The measures of the industry-level productivity gaps from the price and volume data are identical by definition. We define the aggregate TFP gap between Japan and the U.S. as the Domar-weighted average of the industry-level productivity gaps:

(13) $\ln TLI_t = \Sigma_j d_{jt} \ln TLI_{jt},$

where d_{jt} weights are the average, two-country shares of the Domar weights.

The Domar weights multiply industry productivity growth by the share of industry value added in GDP and divide by the share of industry value added in industry output. These weights capture the relative importance of the industry in GDP and the relative importance of value added in the industry's output. Equation (13) provides the framework for quantifying the industry origins of the productivity gap between Japan and the U.S.

Finally, the productivity gaps involve prices and quantities of capital inputs. The price of capital input P_{Kijtc} from asset i in industry j in country c is defined as :

(14) $P_{Kijtc} = \varphi_{ijc} P_{Aijtc},$

where P_{Aijtc} represents the unit price for acquisition of a dollar's worth of assets and the coefficient φ_{ijc} is the annualization factor that transforms the acquisition price into the price of capital services. The annualization factors are constant over time periods.

The elementary level PPP for capital input as of the base year T is defined as:

(15) $PPP_{KijT} = (\varphi_{ijJ} / \varphi_{ijU}) PPP_{AijT}.$

The key to measuring the PPP for capital input is the relative value of the annualization factor $\varphi_{ijJ} / \varphi_{ijU}$ and the PPP for the acquisition of assets PPP_{AijT}. The acquisition price is measured as the purchaser's price PPP for composite goods sold to industry, as described in Section 2.2. The elementary level PPPs for capital input are aggregated to the industry-level by the translog index in Equation (5).

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