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Benchmark 2011 Integrated Estimates of the Japan-U.S. Price Level Index for Industry Outputs

October 2018

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Abstract

This paper provides new benchmark estimates of industry-level price differentials between Japan and the U.S. for 2011 based on a bilateral price accounting model anchored to the Japan-US input-output tables. We apply the model to translate available demand-side data on purchaser's price PPPs for final uses (e.g. the Eurostat-OECD PPPs) and intermediate uses (e.g. the METI survey) to unmeasured producer's price PPPs for industry output. These PPPs allow us to produce price level indexes at the industry level, which we use to assess price competitiveness between Japan and the U.S. Under the nominal exchange rate of 110.6 yen per dollar as of the beginning of July 2018, we estimate that producers in Japan have a pricing advantage in 66 of 106 industries in the manufacturing sector, and in 24 of 50 industries in the service sector. We conclude that price competitiveness of Japanese service industries has considerably improved in the more recent time period. However, Japanese producers have a significant price disadvantage in comparison to their U.S. counterparts in electricity and gas supply, and most of the agricultural producing industries.

Keywords: Purchasing Power Parity, International Input-Output Tables, Price Level Indexes, International Competitiveness

JEL classification: F02, C43, C67

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1 Introduction

Cross country comparisons of international competitiveness at the industry-level are inherently more difficult than aggregate comparisons. The basic issue is that comparing industries is more data demanding than comparing aggregates in general, but this is exacerbated by the fact that price differentials are mainly measured at the level of final expenditures.[1] Price data at the level of final expenditures enables one to compare output across countries at the aggregate level, by estimating the PPP for GDP from the expenditure side. One of the main impediments to comparing industries is the lack of adequate data on price differentials of domestic industry outputs and intermediate inputs across countries. This data gap has greatly limited productivity level comparisons at industry level across countries and in turn, offered little insight into cross-country supply-side efficiency measures and related policy implications (Hamadeh and AbuShanab, 2016; Jorgenson, 2018).

The purpose of this paper is to fill this data gap for the U.S. and Japan. We employ a bilateral price model to measure 2011 benchmark industry-level price level indices (PLIs) for outputs. The PLI is defined as the ratio of the PPP to the market exchange rate. Our starting point is the Isard-type bilateral input-output table (BIOT), that has been developed by the Ministry of Economy, Trade and Industry (METI), Government of Japan for the purpose of analyzing the interdependency among Japanese and the U.S. industries since 1985.[2] METI's Japan-US BIOTs are harmonized to a common and detailed classification of industries[3], and provides supplementary tables on international freight and insurance and tariffs by products in both countries. Although the availability of METI's BIOT is a major advantage in forming Japan-US comparisons (that is, data of this nature is not available for most other countries), METI's compilation terminated after the publication of the 2005 BIOT (METI, 2013). In this paper, we estimate the 2011 BIOT by extending the official 2005 BIOT.

Using the 2011 Japan-US BIOT as an anchor, we postulate an accounting model describing the relationships among producer's prices and purchaser's prices for domestically-produced and imported products. The model reflects the differences in the trade structure, freight and insurance rates, duty tax rates, wholesale and retail trade margins, and transportation costs in each product.[4] Using demand-side data of purchaser's price differentials for final uses, e.g., the PPP estimates in Eurostat-OECD (2012), and for intermediate uses, e.g., *Survey on Foreign and Domestic Price Differentials for Industrial Goods and Services* in METI (2012), the producer's price differentials for outputs are estimated based on our Japan-US bilateral price accounting model. That is, the

[1] For example, the purchasing power parities (PPPs) compiled within the International Comparisons Program (ICP) in Eurostat-OECD (2012) and World Bank (2014).
[2] The first bilateral table between Japan and the U.S. for 1970 was developed in Japan at the Institute of Developing Economies (1978) as a joint project with Keio Economic Observatory (KEO), Keio University in 1978. The METI's Japan-US BIOTs were compiled for the benchmark years of Japanese benchmark IOT, i.e., 1985, 1990, 1995, 2000, and 2005.
[3] The 2005 Japan-US IOT in METI (2013) is defined as the symmetric-IOT with common classification of 173 products. This is estimated based on the Japan's 2005 benchmark IOT and the U.S. 2005 Symmetric IOT developed at INFORUM, University of Maryland, which was extended from the 2002 Benchmark SUT by the U.S. Bureau of Economic Analysis (BEA), Department of Commerce.
[4] The original price model approach to determining the product PPPs between Japan and the U.S. was developed in Jorgenson, Kuroda, and Nishimizu (1987).

model takes available prices on final demand and intermediate uses and converts these to conceptually appropriate industry output and intermediate input prices that are consistent with the input-output tables. The availability of METI's survey on PPPs for intermediate uses is a significant advantage in the Japan-US comparison. This enables us to account for the price differentials for intermediate products like semiconductors, which do not appear in the survey on final demand prices. It is important to note that the PPPs at purchaser's prices are sometimes considerably different for final and intermediate uses even within the same class of product. This could be because the composition and quality of the products may differ between final demand and intermediate input. In our approach, we are able to identify the gap between the two, and account for this by constructing the PPPs for industry outputs as a composite of both.

As globalization has deepened since the early 1990s, it has become more important to consider the impact of the differences in the import prices of the traded goods in Japan and the U.S. The import prices allow us to parse the price of composite goods into that from domestic supply (which feeds into the industry output price) and that coming from imported goods. Our bilateral price model has a sub model to explicitly treat the imports by product from six exogenous economies, i.e., China, Germany, Korea, Malaysia, Taiwan (Republic of China), and Thailand, to Japan and the U.S.

Compared to the previous work in Nomura and Miyagawa (1999 and 2015), we use more price data than the earlier studies. This additional price data allows us to refine our estimates of the unobserved prices in our price model. The total number of price-differential data we use in this paper is 538 at the elementary level, in which each of the price concepts (i.e., for industry or household use, at producer's or purchaser's prices, and including imports or not) are incorporated into the accounting model to pin down the remainder of the prices for which there is no data. For the case that the appropriate data are not available, or their accuracy cannot be checked, the cost index approach is used. Using the cost index approach, the underlying assumption is that the output price relative corresponds to the input price relative. In measuring costs, we include not only the price differentials of products for intermediate uses (estimated in this paper), but also the prices of labor and capital inputs used in production.[5] By construction, the cost index approach imposes zero TFP differential between Japan and the U.S.

The accuracy of the estimated PPPs for industry outputs based on the price model approach depends not only on the quality of purchaser-price PPPs of the composite products for different uses, but also on measures of the margin rates and other related parameters that are used to translate the available data into conceptually appropriate prices to match the input-output table. It should be of note that 2011 as the benchmark year is not necessarily ideal to observe the Japanese economy. The first reason is that the 2011 benchmark estimates in the Japan's system of national accounts (JSNA) depend on the 2011 Economic Census, which was conducted for the first time in the history of Japanese economic statistics. This had the potential to improve the quality of JSNA, but on the other hand, because it was a new Census, the results had the potential to reflect changes in

[5] These are estimated in Jorgenson, Nomura, and Samuels (2018).

methodologies and approaches to measurement. Another reason is the impact of the East Japan great earthquake disaster on March 11, 2011. The earthquake made it difficult to survey some areas in East Japan and to observe the economy, in general. Although it is hard to evaluate the quality of the 2011 benchmark JSNA at present, there are some indications of measurement error in Japan's benchmark input-output table (IOT). Nomura and Miyagawa (2018a) pointed out that the wholesale and retail service values in the 2011 benchmark IOT were considerably underestimated. This paper incorporates their alternative estimates of wholesale and retail margins, which are one of the key parameters in the price model. The sensitivity to this revision is discussed the Appendix.

The remainder of this paper is organized as follows. Section 2 presents our representation of the production systems for Japan and the U.S. that is the basis for our accounting model, and an overview of our methodological framework. The detailed equations to describe the bilateral accounting model are provided in the Appendix. In Section 3 we describe our data sources for the Japan-US BIOT and for the price differentials that feed into the price accounting model. The results are presented in Section 4. Section 5 concludes.

2 Framework

We start with a basic description of our framework. Figure 1 provides the Isard-type bilateral input-output table (BIOT). Entries of the table are in nominal values, but shown here as price times volume to emphasize how this relates to the price accounting model that we present below. Our BIOT separately identifies the imports from six exogenous economies: China, Germany, Korea, Malaysia, Taiwan, and Thailand, and the rest of the world (ROW). In the Isard-type (non-competitive import type IOT) framework (Isard, 1951), all purchases in Japan and the U.S. from foreign countries are recorded separately from the purchases of domestically produced goods and services. The areas surrounded by dotted squares in Figure 1 represent imports to Japan and the U.S. The variables in the BIOT are defined in the Appendix.

The prices of domestically produced products are evaluated at producer's prices (including indirect taxes required for purchasers). The prices of imported products in Japan and the U.S., from the U.S. and Japan, respectively, are evaluated at FOB (free on board) prices (producers' prices plus margin and transportation costs from producers to customs). Thus, the freight and insurance and tariff embedded in imports (in Japan-US trade) and the net indirect taxes required in imported countries (in Japan or the U.S.) are separately recorded from the FOB-price imports. The imports from exogenous economies are evaluated at the prices including CIF (cost, insurance, and freight), tariff, and the net indirect taxes embedded in imports (in Japan or the U.S.).

		Intermediate uses (N)		Household consumption (H)		Government consumption & Gross capital formation (Z)		Exports to exogenous countris (E)	Gross output (X)
		Japan (J)	the U.S. (U)	Japan (J)	the U.S. (U)	Japan (J)	the U.S. (U)		
Products in	Japan (J)	$\frac{p^{d,I}_{J,i}X_{JJ,ij}}{e_{J/U}}$	$\frac{p^{d,I}_{JU,i}X_{JU,ij}}{e_{J/U}}$	$\frac{e_{J/U}p^{d,H}_{J,i}X_{JJ,iH}}{e_{J/U}}$	$\frac{p^{d,H}_{JU,i}X_{JU,iH}}{e_{J/U}}$	$\frac{p^{d,I}_{J,i}X_{JJ,iZ}}{e_{J/U}}$	$\frac{p^{d,I}_{JU,i}X_{JU,iZ}}{e_{J/U}}$	$\frac{p^{d}_{JE,i}X_{JE,iE}}{e_{J/U}}$	$\frac{p^{d}_{J,i}X_{J,i}}{e_{J/U}}$
	the U.S. (U)	$p^{d,I}_{UJ,i}X_{UJ,ij}$	$p^{d,I}_{U,i}X_{UU,ij}$	$p^{d,H}_{UJ,i}X_{UJ,iH}$	$p^{d,H}_{U,i}X_{UU,iH}$	$p^{d,I}_{UJ,i}X_{UJ,iZ}$	$p^{d,I}_{U,i}X_{UU,iZ}$	$p^{d}_{UE,i}X_{UE,iE}$	$p^{d}_{U,i}X_{U,i}$
Freight and insurance for the Japan-US trade		$\tau^{f}_{UJ}p^{fob,I}_{UJ,i}X_{UJ,ij}$	$\frac{\tau^{f}_{JU}p^{fob,I}_{JU,i}X_{JU,ij}}{e_{J/U}}$	$\tau^{f}_{UJ}p^{fob,H}_{UJ,i}X_{UJ,iH}$	$\frac{\tau^{f}_{JU}p^{fob,H}_{JU,i}X_{JU,iH}}{e_{J/U}}$	$\tau^{f}_{UJ}p^{fob,I}_{UJ,i}X_{UJ,iG}$	$\frac{\tau^{f}_{JU}p^{fob,I}_{JU,i}X_{JU,iZ}}{e_{J/U}}$		
Tariff for the Japan-US trade		$\tau^{r}_{UJ}p^{fob,I}_{UJ,i}X_{UJ,ij}$	$\frac{\tau^{r}_{JU}p^{fob,I}_{JU,i}X_{JU,ij}}{e_{J/U}}$	$\tau^{r}_{UJ}p^{fob,H}_{UJ,i}X_{UJ,iH}$	$\frac{\tau^{r}_{JU}p^{fob,H}_{JU,i}X_{JU,iH}}{e_{J/U}}$	$\tau^{r}_{UJ}p^{fob,I}_{UJ,i}X_{UJ,iZ}$	$\frac{\tau^{r}_{JU}p^{fob,I}_{JU,i}X_{JU,iZ}}{e_{J/U}}$		
Net indirect taxes on imports of the Japan-US trade		$TX^{I}_{UJ,ij}$	$TX^{I}_{JU,ij}$	$TX^{H}_{UJ,iH}$	$TX^{H}_{JU,iH}$	$TX^{I}_{UJ,iZ}$	$TX^{I}_{JU,iZ}$		
Import from exogenous countries at the price of cif, tariff, and net indirect taxes (E)	China (C)	$\frac{p^{m,I}_{CJ,i}X_{CJ,ij}}{e_{J/U}}$	$p^{m,I}_{CU,i}X_{CU,ij}$	$\frac{p^{m,H}_{CJ,i}X_{CJ,iH}}{e_{J/U}}$	$p^{m,H}_{CU,i}X_{CU,iH}$	$\frac{p^{m,I}_{CJ,i}X_{CJ,iZ}}{e_{J/U}}$	$p^{m,I}_{CU,i}X_{CU,iZ}$		
	Germany (G)	$\frac{p^{m,I}_{GJ,i}X_{GJ,ij}}{e_{J/U}}$	$p^{m,I}_{GU,i}X_{GU,ij}$	$\frac{p^{m,H}_{GJ,i}X_{GJ,iH}}{e_{J/U}}$	$p^{m,H}_{GU,i}X_{GU,iH}$	$\frac{p^{m,I}_{GJ,i}X_{GJ,iZ}}{e_{J/U}}$	$p^{m,I}_{GU,i}X_{GU,iZ}$		
	Korea (K)	$\frac{p^{m,I}_{KJ,i}X_{KJ,ij}}{e_{J/U}}$	$p^{m,I}_{KU,i}X_{KU,ij}$	$\frac{p^{m,H}_{KJ,i}X_{KJ,iH}}{e_{J/U}}$	$p^{m,H}_{KU,i}X_{KU,iH}$	$\frac{p^{m,I}_{KJ,i}X_{KJ,iZ}}{e_{J/U}}$	$p^{m,I}_{KU,i}X_{KU,iZ}$		
	Malaysia (M)	$\frac{p^{m,I}_{MJ,i}X_{MJ,ij}}{e_{J/U}}$	$p^{m,I}_{MU,i}X_{MU,ij}$	$\frac{p^{m,H}_{MJ,i}X_{MJ,iH}}{e_{J/U}}$	$p^{m,H}_{MU,i}X_{MU,iH}$	$\frac{p^{m,I}_{MJ,i}X_{MJ,iZ}}{e_{J/U}}$	$p^{m,I}_{MU,i}X_{MU,iZ}$		
	Taiwan (W)	$\frac{p^{m,I}_{WJ,i}X_{WJ,ij}}{e_{J/U}}$	$p^{m,I}_{WU,i}X_{WU,ij}$	$\frac{p^{m,H}_{WJ,i}X_{WJ,iH}}{e_{J/U}}$	$p^{m,H}_{WU,i}X_{WU,iH}$	$\frac{p^{m,I}_{WJ,i}X_{WJ,iZ}}{e_{J/U}}$	$p^{m,I}_{WU,i}X_{WU,iZ}$		
	Thailand (T)	$\frac{p^{m,I}_{TJ,i}X_{TJ,ij}}{e_{J/U}}$	$p^{m,I}_{TU,i}X_{TU,ij}$	$\frac{p^{m,H}_{TJ,i}X_{TJ,iH}}{e_{J/U}}$	$p^{m,H}_{TU,i}X_{TU,iH}$	$\frac{p^{m,I}_{TJ,i}X_{TJ,iZ}}{e_{J/U}}$	$p^{m,I}_{TU,i}X_{TU,iZ}$		
	ROW (R)	$\frac{p^{m,I}_{RJ,i}X_{RJ,ij}}{e_{J/U}}$	$p^{m,I}_{RU,i}X_{RU,ij}$	$\frac{p^{m,H}_{RJ,i}X_{RJ,iH}}{e_{J/U}}$	$p^{m,H}_{RU,i}X_{RU,iH}$	$\frac{p^{m,I}_{RJ,i}X_{RJ,iZ}}{e_{J/U}}$	$p^{m,I}_{RU,i}X_{RU,iZ}$		
Value added		$\frac{VA_{J,j}}{e_{J/U}}$	$VA_{U,j}$						
Gross output		$\frac{p^{d}_{J,j}X_{J,j}}{e_{J/U}}$	$p^{d}_{U,j}X_{U,j}$						

Figure 1: Japan-US Input-Output Table (the Isard-Type)

Note: See Appendix for the definition of the variables.

Based on the production system in Figure 1, we specify an accounting model describing producer's prices and purchaser's prices for domestically-produced and imported products that takes into account the trade structure, freight and insurance rates, duty tax rates, wholesale and retail trade margins, and transportation costs in each product. The details of the equations are provided in the Appendix. Our objects of interest are the following PLIs for each product i, which are defined as price level in Japan relative to the U.S., divided by the nominal exchange rate:

$\mathbf{P}_i^{d}$ PLI for domestic outputs at producer's price,

$\mathbf{P}_i^{d,l}$ PLI for domestic outputs at producer's price (see definition of l below),

$\mathbf{P}_i^{c,l}$ PLI for composite products (domestic products and imports) at producer's price, and

$\mathbf{P}_i^{pc,l}$ PLI for composite products (domestic products and imports) at purchaser's price, where l stands for the demand group.[6] We define six groups of demands, denoting:

N for intermediate uses,

H for household consumption (including consumption by NPISHs),

G for government consumption,

F for investment (GFCF and changes in inventories) by industries and government,

E for exports to exogenous economies, and

M for imports,

and the following three broad groups of the demands,

Z for domestic final demand excluding household consumption (Z={G, F}),

I for domestic demand by industries and government (I={N, G, F})[7], and

D for domestic demand (D={I,H}={N, H, G, F}).

Figure 2 illustrates the relationships among the PLIs and shows four paths used in estimation to go from observed data to the unmeasured the PLIs of interest. The PLI surrounded by each box indicates the observed PLI and the corresponding directional arrows indicate the estimation used conditional on the observed data.

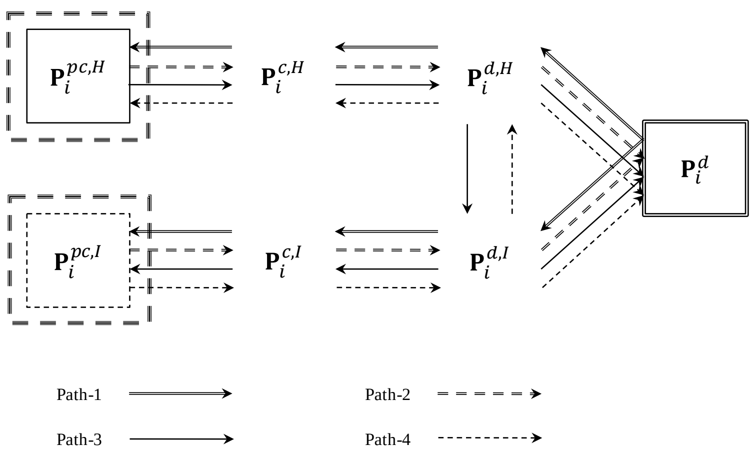

Figure 2: Price Deviation Paths

Path-1 starting with the box on the right shows the case where the producer-price PLI of domestic outputs $\mathbf{P}_i^d$ is available based on surveys. In this case, the difference between $\mathbf{P}_i^{d,I}$ (the arrow to the lower left in Figure 2) and $\mathbf{P}_i^{d,H}$ (the arrow to the upper left) is due to the difference in the treatment of consumption taxes. Next, continuing to move left in the diagram, the producer-price PLI of composite products for intermediate use $\mathbf{P}_i^{c,I}$ and for household use $\mathbf{P}_i^{c,H}$ are derived by taking into account the difference in import prices for Japan and the U.S. (based on Equation

[6] To distinguish the price level index from the prices, we use the bold as $\mathbf{P}_i^d$. These Japan-US PLIs are defined as Japan's price over the U.S. prices as in Equation (20). Although they are described as $\mathbf{P}_{J/U,i}^d$ in the Appendix to identify the transactions Japan, the U.S., and exogenous economies, the subscript "J/U" is omitted in main text.

[7] Since the government consumption is defined at the actual base, the products for I={N, G, F} mainly refer the products consumed for industries' intermediate uses (N) and investment by industries and government (F). For simplicity, we use I to denote demand for industry uses.

(21) in the Appendix). Finally, the purchaser-price PLI of the products for intermediate use $\mathbf{P}_i^{pc,I}$ and for household use $\mathbf{P}_i^{pc,H}$ are estimated by including the difference in the trade margins and the transportation costs by product between Japan and the U.S., based on Equation (30).

Path-2 is the case where data for the purchaser-price PLI of the products for industry use $\mathbf{P}_i^{pc,I}$ and household use $\mathbf{P}_i^{pc,H}$ are available. Based on this data, $\mathbf{P}_i^{c,I}$ and $\mathbf{P}_i^{c,H}$ (the arrow to the right in Figure 2) are calculated based on Equation (30). And then, $\mathbf{P}_i^{d,I}$ and $\mathbf{P}_i^{d,H}$ are estimated in accordance with Equation (23) and $\mathbf{P}_i^{d}$ is derived as the aggregate based on the Equation (24).

In Path-3 scenarios, only the purchaser-price PLI of the products for household use $\mathbf{P}_i^{pc,H}$ is available as observations (like the Eurostat-OECD PPPs). By considering the differences in trade margins and the transportation costs, $\mathbf{P}_i^{c,H}$ and $\mathbf{P}_i^{d,H}$ are estimated based on Equations (30) and (23), respectively. In this case, $\mathbf{P}_i^{d,I}$ is derived (the arrow pointing down in Figure 2) by considering the difference in consumption taxes and $\mathbf{P}_i^{d}$ is determined using $\mathbf{P}_i^{d,I}$ and $\mathbf{P}_i^{d,H}$ based on Equation (24). Additionally, $\mathbf{P}_i^{c,I}$ and $\mathbf{P}_i^{pc,I}$ are estimated by taking into account the difference in import prices, the percentage of imports, the trade margins, and the transportation costs between Japan and the U.S,. In Path-4 scenarios, $\mathbf{P}_i^{pc,I}$ is observed instead of $\mathbf{P}_i^{pc,H}$ as in the Path-3 scenario, but the process to estimate the other PLIs is similar.

3 Data and Measurement

3.1 2011 Japan-US BIOT

In measuring the 2005 benchmark PLIs, Nomura and Miyagawa (2015) expanded the 2005 Japan-US BIOT (METI, 2013) to identify the imports from six exogenous economies; China, Germany, Korea, Malaysia, Taiwan (Republic of China), and Thailand, and modified the table to account for Japan's consumption tax. Since the introduction of the consumption tax in 1989, in the current JSNA and Japan's benchmark IOT, the values for intermediate uses are recorded as the prices including not only non-deductible consumption taxes, but also deductible ones, resulting in an inconsistency between prices recorded in the accounts and the net prices actually paid by purchasers. In addition, consumption taxes (deductible and non-deductible) are not separately estimated from other indirect taxes by industry. Since METI's 2005 Japan-US BIOT follows this price definition used in JSNA, it is difficult to compare Japan's prices with those in the U.S. The 2005 BIOT was revised to define output at basic prices in Nomura and Miyagawa (2015), and we follow the same approach.

Using the adjusted 2005 BIOT as the base table, this paper estimates the 2011 BIOT, by considering changes in production and trade from 2005 to 2011. Our adjustments are based on the official national accounts and trade statistics in Japan and the U.S. The international trade data of Japan and the U.S. from the six exogenous countries and the ROW are extended in each product based on the import data by product and by county published in the UN Comtrade Database.

To estimate the model, the trade matrix among Japan and the U.S., the six exogenous countries, and the ROW is required as in Equation (34). In measurement of the PPPs for 2005 in Nomura and Miyagawa (2015), these matrices for industry use and household use were developed based on the

2005 Asian International Input-Output Table published by Institute of Developing Economies (2013), which covers Japan, the U.S., China, Korea, Malaysia, Taiwan, and Thailand, and the WIOD (World Input-Output Database) in Timmer et al. (2015), which covers Japan, the U.S., China, Germany, Korea, and Taiwan. In this paper, the WIOD is used to update the trade matrices from 2005 to 2011; other trade relationships are assumed to be unchanged due to the lack of the 2011 Asian International IOT.

3.2 Elementary Level PLIs

We use price-differential data obtained from Eurostat-OECD (2012), METI (2012), and many sources published by agencies and ministries of the Government of Japan and the private business sector as our starting point.[8] The total number of price data at the elementary level used in this study was 538. Since the number of products in our model based on the 2011 Japan-US BIOT is 174, on average about 3 price data points are used to estimate the price of one product in our model. In some cases, data with different price concepts at the elementary level are integrated based on our price model, e.g., the PLIs for industry use and household use are integrated as described in Path-2 in Figure 2. Sometimes the price data at the elementary level are highly disaggregated within one of our 174 products of interest. For example in chemical products, the PPPs for highly disaggregated products for intermediate uses are available in METI (2012). In this case, the product level PLIs are calculated as Törnqvist indices using the elementary level PLIs. If the weight for the elementary level is unavailable, the product's PLI is calculated as a simple geometric average.

Table 1 presents the concepts of the collected data at the elementary level by broad product. Each row corresponds to a sector of Central Product Classification Ver.2. One of the most important data sources is the Eurostat-OECD PPPs. At the most detailed level, the Eurostat-OECD 2011 includes price data for 206 products which are called "basic headings." The survey observes PPPs at purchaser's prices of composite products purchased by households or used as investment. As shown in Table 1, 129 price data for households and 27 price data for investment were used to correspond to $\mathbf{P}_i^{pc,H}$ and $\mathbf{P}_i^{pc,F}$, respectively.[9]

For intermediate products, METI's *Survey on Foreign and Domestic Price Differentials for Industrial Goods and Services* is the main data source.[10] This survey has been conducted every year between 1993 and 2012 and every two years since 2012. The 2011 survey (METI, 2012), collected price data for 226 goods and 61 services for intermediate uses, and covered 6 countries namely, Japan, the U.S., China, Germany, Korea, and Taiwan. Data in this survey is measured in purchaser's price PPPs. As seen in Table 1, 272 data are collected from this survey and used to estimate $\mathbf{P}_i^{pc,N}$, in our framework.

[8] In the context of Japan-US comparisons, a significant advantage is the availability of much richer data on price differentials among major industrialized countries. These have been gathered by the agencies and ministries of the Government of Japan since the late 1980s, as a response to an important policy focus on international price differentials after the Plaza Accord of 1985 resulted in the rapid appreciation of the Japanese yen.

[9] In Table 1, the purchaser's demand price for intermediate uses $\mathbf{P}_i^{pc,N}$ and for investments $\mathbf{P}_i^{pc,F}$ are distinguished. Both of them are treated as $\mathbf{P}_i^{pc,I}$ in the price framework explained in Section 2.

[10] The title of METI's survey was revised in 2011 from the previous title: *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input*.

Table 1: Number of Data on Price Differentials at Elementary Level

	Purchaser's price									Producer's price				Total
	Intermediate use $\mathbf{P}_i^{pc,N}$				Household consumption $\mathbf{P}_i^{pc,H}$				Investment $\mathbf{P}_i^{pc,F}$	$\mathbf{P}_i^{d}$				
CPC code	METI PPP survey	Other PPP surveys	Other surveys on unit prices	Total	Eurostat -OECD PPPs	Other PPP surveys	Other surveys on unit prices	Total	Eurostat -OECD PPPs	Other surveys on unit prices	Cost index	Reference PPP	Total	
0 Agriculture, forestry and fishery					6			6		10	3		13	19
1 Ores and minerals; electricity, gas and water	10	3		13			1	1		5		1	5	19
2 Food, beverages and tobacco; textiles, apparel and leather	1			1	47	5		52			6	1	6	59
3 Other transportable goods, except metal products, machinery, equipment	76	6	7	89	14	11	1	26	3	3	2	5	5	123
4 Metal products, machinery and equipment	121			121	20	7	7	34	18		1	8	1	174
5 Constructions and construction services									4					4
6 Trade; accommodation, food and beverage serving; transport	22	5	1	28	9	1	1	11		2		2	2	41
7 Financial and related services; real estate; rental and leasing services	15			15	5	1	1	7		2	1		3	25
8 Business and production services	19			19	8	5		13	1		5		5	38
9 Community, social and personal services	8		3	11	20	1		21	1		3		3	36
Total	272	14	11	297	129	31	11	171	27	22	21	17	43	538

Source: Our estimates.

Although these two surveys don't cover all the products, there are rich data on international price differentials based on the surveys implemented by a number of Japanese ministries. We use *Survey of PPPs on Consumer Goods and Services* (METI, 2003), *Survey of PPPs on Drugs and Medical Products* (Ministry of Health, Labour and Welfare, 2003), *Survey of Retail Prices of Food Products in Tokyo and Foreign Major 6 Cities* (Ministry of Agriculture, Forestry and Fisheries, 2006), and others.[11] From these surveys, 14 price data for intermediate use and 31 price data for household use are used to estimate $\mathbf{P}_i^{pc,N}$ and $\mathbf{P}_i^{pc,H}$ respectively.[12]

In addition, other surveys on unit prices are used in this study, where appropriate. For example, the output prices of some agricultural products evaluated at producer's price are directly observed from *Table on Value and Quantity* (*Butsuryo Hyo*) which was compiled as a supplementary table of the Japanese 2011 IOT and *Rice Outlook*, *Oil Crops Outlook*, or *Sugar and Sweeteners Outlook* published by the U.S. Department of Agriculture. The output prices for cattle, poultry and hog in Japan and the U.S. are directly obtained from the statistical data on livestock and its products published by the Agriculture and Livestock Industries Corporation, Japan. The output prices of coal, crude oil, and natural gas are obtained from *Trends of the Japanese Mining Industry* published by METI and *Annual Energy Review* published by the U.S. Energy Information Administration. As a result, 22 price data are used to determine $\mathbf{P}_i^{d}$ directly without having to appeal to the price

[11] In addition, *Survey of PPPs on Transportation and Related Services* (Ministry of Land, Infrastructure and Transport, 2007), *Survey of PPP on Information Services* (Ministry for Internal Affairs and Communications, 2011) and *Survey of PPPs on Major Consumer Goods and Services* (Cabinet Office, 2001) are used in our study.

[12] These data are estimated for different years and different stages of demand. The differences in timing of the surveys were adjusted using the CPI and PPI in both countries. We have reconciled these data within our price model.

model. Finally, there are surveys that provide information on unit prices paid by purchasers; these additional surveys provide 11 price data points that are used to measure intermediate and household purchase prices, $\mathbf{P}_i^{pc,N}$ and $\mathbf{P}_i^{pc,H}$, respectively.

In the process to discern the producer's price PLIs for outputs from the purchaser's price PLIs based on the price model, the PLIs of wholesale and retail services have a significant role. Nomura and Miyagawa (2018a) pointed out that the outputs of the wholesale and retail sectors in the 2011 benchmark IOT in Japan appeared to be considerably underestimated and provided alternative estimates of wholesale and retail margins based on microdata of Census of Commerce.[13] This paper uses these margin rate and PLI estimates for 2011. These data are counted as two data points in "Other surveys on unit prices" in Table 1. A sensitivity analysis to our choice of margins is presented in the Appendix.

The cost approach is also adopted for some products whose prices are difficult to directly observe. In the cost approach, the producer-price PLIs of domestic products are estimated by the PLIs of all intermediate products we estimated in this paper and the estimates of the PLIs for labor and capital inputs estimated in Jorgenson, Nomura, and Samuels (2018), aggregated using the weights of the cost structures obtained from the 2011 Japan-US BIOT. Figure 3 presents the PPPs for labor and capital inputs at the aggregate level for the period 1990–2015 in Jorgenson, Nomura, and Samuels (2018). During the recent quarter of century, the PPPs for factor inputs have considerably declined. In particular, the PPP for labor input declined by half.[14] Long-term declines in PPPs for factor inputs translates to declines in PPPs for industry outputs based on the cost approach, but obviously only for products that use the cost index approach (21 out of 538 products).

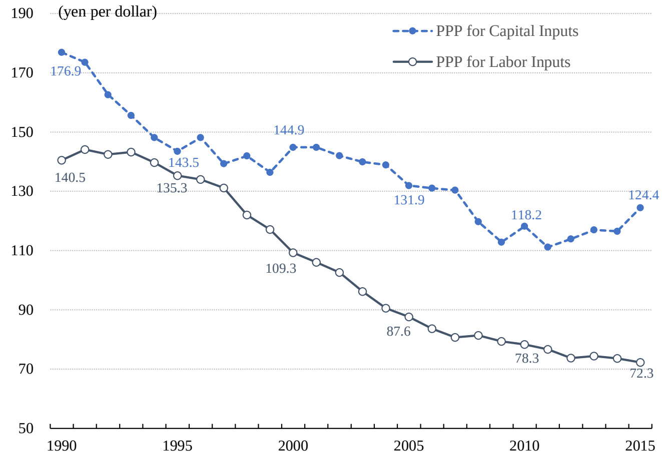

Figure 3: PPPs for Capital and Labor Inputs in 1990–2015

For a small set of products, we apply the reference PPP approach, in which the PPPs of the

[13] In Nomura and Miyagawa (2018b), the output PPP for wholesale service is estimated based on 82 goods for household use and 110 goods for industry use and the output PPP for retail service is estimated based on 87 goods for household use and 19 goods for industry use.

[14] The quality-adjusted price of labor inputs has continued to decline in Japan for 15 years from 1997 to 2012 (Nomura and Shirane, 2014).

similar products are applied. In this study, the cost index approach is applied for 21 elementary level products such as government service, education, and research (that is, we back out the relative output prices by assuming that the gap in total factor productivity between Japan and the U.S. is zero), and the reference PPP approach is applied for 17 elementary level products.

3.3 Product Level PLIs

As shown in Table 1, many of the observed price data is based on purchaser's demand prices. Therefore, $\mathbf{P}_i^d$ is estimated in this study by applying our price models to $\mathbf{P}_i^{pc,I}$ and/or $\mathbf{P}_i^{pc,H}$ for a large share of products. Table 2 presents the composition of our estimation methods. Each row shows the Central Product Classification Ver.2, and the number in the column corresponds to the number of products classified in each group (the total is the number of all products, 174).

Table 2: Number of Products by Price Deviation Path

	Path-1	Path-2	Path-3	Path-4				
	Producer's price	Purchaser's price						
		Household &Industry use	Household use	Industry use	(Path-4.1) Intermediate uses&Investment	(Path-4.2) Intermediate uses	(Path-4.3) Investment	Total
CPC code	$\mathbf{P}_i^d$	$\mathbf{P}_i^{pc,H}$& $\mathbf{P}_i^{pc,I}$	$\mathbf{P}_i^{pc,H}$	$\mathbf{P}_i^{pc,I}$	$\mathbf{P}_i^{pc,N}$ & $\mathbf{P}_i^{pc,F}$	$\mathbf{P}_i^{pc,N}$	$\mathbf{P}_i^{pc,F}$	
0 Agriculture, forestry and fishery	8	2	2					12
1 Ores and minerals; electricity, gas and water	5	1		3		3		9
2 Food, beverages and tobacco; textiles, apparel and leather	2	6	17					25
3 Other transportable goods, except metal products, machinery, equipment	6	11	4	13		13		34
4 Metal products, machinery and equipment	4	15	5	21	4	12	5	45
5 Constructions and construction services				4			4	4
6 Trade; accommodation, food and beverage serving; transport	2	7	3	2		2		14
7 Financial and related services; real estate; rental and leasing services		4	2	1		1		7
8 Business and production services	3	6	1	1		1		11
9 Community, social and personal services	2	4	4	3		3		13
Total	32	56	38	48	4	35	9	174

Source: Our estimates. Note: The number of products (32) in Path-1 includes 9 products based on the cost approach and 7 products based on the reference PPP approach.

According to Table 2, Path-1, which takes $\mathbf{P}_i^d$ as data was applied to 32 products, which were mainly classified in Agriculture and Mining sector. Since the estimation of $\mathbf{P}_i^d$ is the target of this study, Path-1 based on the directly observed price data is the most preferable approach. The PLIs for 56 products are estimated by Path-2 process, in which $\mathbf{P}_i^{pc,I}$ and $\mathbf{P}_i^{pc,H}$ are observed first and output prices are estimated via the accounting model. This is the most frequent case among four price deviation paths and can be considered the second best path. Path-3 determines $\mathbf{P}_i^{pc,H}$ first. 38 products, most of which are final consumption goods and services, are estimated by this method. Although Path-4, which takes as data $\mathbf{P}_i^{pc,I}$, is similar to Path-3, this is divided into three sub cases depending on the kinds of the observed PLIs. In the first case, written as Path-4.1, the PLI of purchaser's demand price for industries $\mathbf{P}_i^{pc,I}$ is determined using both the PLI of the products for intermediate use and investment, $\mathbf{P}_i^{pc,N}$ and $\mathbf{P}_i^{pc,F}$, respectively. Path-4.1 is applied only to 4 products classified in Metal products, machinery, and equipment. Path-4.2 uses $\mathbf{P}_i^{pc,N}$ to determine $\mathbf{P}_i^{pc,I}$ and 35 products belong to this case. The PLIs of only 9 products are estimated by Path-4.3, which uses only $\mathbf{P}_i^{pc,F}$ to determine $\mathbf{P}_i^{pc,I}$.

4 Results

Table 3 compares the PPPs for GDP developed in this paper and the Eurostat-OECD PPPs in 2011. Our estimate of the PPP for GDP, which is derived from aggregating the PPPs for industry-GDP at basic prices, is 109.0 yen per dollar, which closely resembles the Eurostat-OECD PPP (107.5 yen per dollar) in 2011.[15] Compared to the Eurostat-OECD PPP, our expenditure-side estimates are somewhat lower in household consumption and building and construction (B&C) of GFCF (gross fixed capital formation) and higher in machinery and equipment (M&E) of GFCF.[16]

Table 3: Aggregated PPPs in 2011

PPP for	GDP	Household consumption	GFCF	B&C	M&E
Our estimates	109.0	113.4	116.6	113.7	104.0
Eurostat-OECD PPPs	107.5	116.1	110.0	114.0	99.2

Unit: yen per dollar. Source: Our estimates. Note: B&C is building and construction and M&E is machinery and equipment.

Figure 4 shows the extrapolated estimates of PPPs for GDP and household consumption from 2011 to 2016, using our benchmark PPP estimates in 2011 and the price indices from the national accounts in Japan (ESRI, Cabinet Office) and the U.S. (BEA) from 2011 to 2016, compared to the Eurostat-OECD estimates. The trends are similar, but our estimate of the PPP for GDP is higher by 2–3 yen per dollar, reflecting the higher benchmark estimates. However, in the PPP estimate for household consumption our benchmark estimate is slightly lower than the Eurostat-OECD PPP, but they are quite similar in 2014–2016. In 2016, our estimates of PPPs for GDP and household consumption are 104.1 and 107.8 yen per dollar, respectively. The current exchange rate of 110.6 yen per dollar as of the beginning of July 2018 is above our aggregate PPP estimate. As a result, both producers and consumers in Japan benefit from price advantages under the current exchange rate. The recent depreciation of the Yen can be tied to the adoption of quantitative easing by the Bank of Japan, followed by the election of Prime Minister Shinzo Abe in December 2012.[17]

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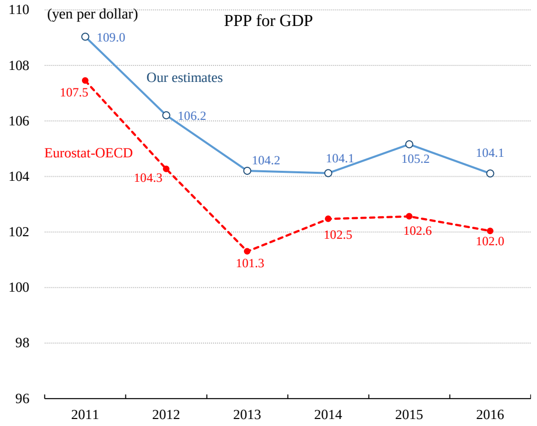
[15] The close relationship between our estimate of the aggregate PPP for household consumption and the Eurostat-OECD PPP is expected since we used their PPP data for many consumer products at the elementary level. The relationship between our estimate of the PPP for GDP and the Eurostat-OECD measure is slightly more complicated. Conceptually, these measure the same object. But in practice our approach to constructing the PPP for government is based on total quality-adjusted input prices including capital and labor services and intermediate inputs, while the Eurostat-OECD approach is based on reference PPPs applied to the components of gross output. See box 9.2 in Eurostat-OECD (2012).

[16] In the 2005 PPPs in Nomura and Miyagawa (2015), the gaps in the estimates for M&E of GFCF were much larger as 126.1 yen per dollar of our estimates, compared to 164.0 in the Eurostat-OECD PPP. These gaps are considerably narrowed in the 2011 PPP estimates in Table 3.

[17] The historical stories on the price competitiveness and the market exchange rates are provided in Jorgenson, Nomura, and Samuels (2018).



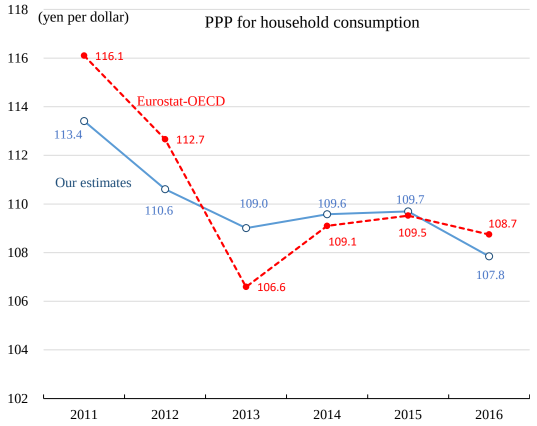


Figure 4: Extended PPPs for GDP and Household Consumption in 2011–2016

Table 4 presents the estimated PPP results for 2011 based on the ISIC classification.[18] The first four columns present the price differentials in domestic outputs (the PPP excluding net indirect taxes, including taxes, for industry use, and for household use) and the next four columns show the PPPs for the composite of domestic and imported products (two PPPs at producer's prices and two at purchaser's prices). And the last two columns indicate the price differentials between Japan and the U.S. in their imports.[19]

Our estimates show there are large differences among the PPP estimates across concepts, implying that it is important to account for conceptual differences in price measures when making international comparisons. For example, consider Motor vehicles. We use this example to highlight two pertinent issues. The first issue is that observed differences in prices paid by household and industry have important implications for measuring relative prices in domestic product, and the second issue that purchaser's prices embed the margin that must be stripped out in measuring domestic product. This becomes evident in examining the various PPPs for Motor vehicles and trailers. For simplicity, consider as a starting point the observation that the PPP for imports of Motor vehicles and trailers is 79.3 yen per dollar for industry use and 77.4 yen per dollar for household use. While these are relatively similar, it will become evident that this similarity plays an important role in backing out the PPP for domestic product. The next PPP to consider in this example is the purchase price the purchaser-price PPPs, which cover domestic products and imports. These are 83.9 and 122.8 yen per dollar for industry and household uses, respectively. The model must reconcile these observed prices, that is: the PPP for industry use is slightly above the import PPP, while the PPP for household use is significantly above the PPP. By stripping off the margins paid on sales to households and industry, the model estimates that the internally consistent producer-price PPP of the Motor vehicles and trailers is estimated to be 79.9 and 95.8 yen per dollar for industry and household use, respectively. Finally, as a composite of the products produced for

[18] In some products of 174 products, the unpublished data at the most detailed level (basic headings) of the Eurostat-OECD PPPs are directly used as $\mathbf{P}_i^{pc,H}$. Since they are not in the public domain, we use 42 types of the broad product group for describing the demand-side PLIs. We aggregate to the ISIC classification using Törnqvist aggregation over the 173 industries.
[19] The differences in the quality of products imported by Japan and the U.S. may be somewhat reflected in the price differentials of imports from exogenous countries, although conceptually this should be counted in the volume differentials.

industry and household, the PPP for output is estimated to be 87.9 yen per dollar. At the exchange rate of 79.8 on average in 2011, using the PPP for household purchases of motor vehicles (122.8) yields a considerably different (and conceptually inappropriate) measure of competitiveness compared to the (conceptually appropriate) 87.9 yen per dollar.

Table 4: PPPs by Different Price Concept in 2011

	Domestic products				Composite products				Imports	
	$\mathbf{PPP}_i^{d*}$	$\mathbf{PPP}_i^{d}$	$\mathbf{PPP}_i^{d,I}$	$\mathbf{PPP}_i^{d,H}$	$\mathbf{PPP}_i^{c,I}$	$\mathbf{PPP}_i^{c,H}$	$\mathbf{PPP}_i^{pc,I,}$	$\mathbf{PPP}_i^{pc,H}$	$\mathbf{PPP}_i^{m,I}$	$\mathbf{PPP}_i^{m,H}$
A - Agriculture, forestry and fishing	197.7	192.8	237.5	110.1	201.5	104.9	205.4	133.5	97.4	73.9
B - Mining and quarrying	236.1	223.7	214.9	251.6	154.1	---	205.2	---	110.0	---
C - Manufacture	88.6	91.9	92.8	117.4	88.1	103.4	93.0	115.8	79.9	76.8
10 - Food products	138.3	142.6	160.4	150.9	134.5	131.4	167.3	168.0	80.7	83.7
11 - Beverages	102.1	131.2	138.2	116.9	135.0	115.8	136.5	121.0	108.3	102.7
12 - Tobacco products	27.1	69.9	66.7	70.1	---	69.5	---	68.9	---	66.3
13 - Textiles	104.6	105.4	107.7	89.7	104.8	---	117.9	---	115.1	68.6
14 - Wearing apparel	129.5	134.8	129.5	136.0	---	71.6	---	103.7	61.4	61.5
15 - Leather and related products	50.6	52.6	94.9	54.8	---	61.4	---	108.6	62.9	63.5
16 - Wood and wood products, except furniture	102.1	102.4	99.1	128.4	92.5	---	98.9	---	76.1	---
17 - Paper and paper products	84.2	84.6	85.4	81.0	82.4	---	94.9	---	52.5	45.3
18 - Printing and reproduction of recorded media	77.8	78.1	77.0	95.4	77.2	---	80.3	---	---	---
19 - Coke and refined petroleum products	103.5	127.8	119.0	151.8	116.2	140.3	117.1	140.8	104.3	96.3
20 - Chemicals and chemical products	77.1	77.7	86.8	43.8	81.4	44.8	87.2	82.4	66.9	52.0
21 - Pharmaceutical products	74.8	76.1	82.7	65.7	80.6	67.5	75.9	79.7	67.9	67.6
22 - Rubber and plastics products	83.1	83.5	79.6	108.2	80.3	---	79.0	---	83.6	98.2
23 - Other non-metallic mineral products	91.1	91.6	94.1	105.9	90.0	---	94.3	---	57.2	64.6
24 - Basic metals	77.7	77.7	81.2	69.3	81.9	---	81.7	---	83.9	86.0
25 - Fabricated metal products, except M&E	70.2	70.5	72.5	92.5	71.3	---	78.3	---	61.7	---
26 - Computer, electronic and optical products	90.5	91.8	94.0	111.9	88.6	102.6	92.3	91.7	84.9	93.2
27 - Electrical equipment	64.4	64.7	61.5	151.7	59.0	---	59.3	---	87.5	86.7
28 - Machinery and equipment n.e.c.	119.4	119.6	122.1	129.3	111.7	---	116.2	---	74.8	76.3
29 - Motor vehicles and trailers	87.9	88.7	85.9	104.0	79.9	95.8	83.9	122.8	79.3	77.4
30 - Other transport equipment	108.5	108.4	108.4	100.1	---	---	---	---	---	81.6
31 - Furniture	117.9	119.1	122.3	108.6	101.6	---	103.6	---	61.4	59.5
32 - Other manufacturing	126.1	128.5	103.9	208.9	97.1	127.7	114.9	105.4	83.0	87.9
33 - Repair and installation of machinery and equipment	86.6	86.8	82.8	148.6	85.6	---	87.5	---	90.0	---
D - Electricity, gas, steam and air conditioning supply	208.2	209.6	219.5	204.1	218.7	203.7	218.3	203.7	---	---
E - Water supply	92.4	93.7	92.8	95.9	92.8	95.9	92.9	96.0	---	---
F - Construction	102.2	102.1	105.5	65.3	105.5	65.3	105.5	65.3	---	---
G - Wholesale and retail trade	134.7	138.3	137.8	139.4	133.3	138.4	132.9	138.4	57.9	65.6
H - Transportation and storage	119.4	121.4	106.6	165.6	99.9	153.6	99.7	154.1	70.4	101.1
I - Accommodation and food service activities	103.9	107.5	104.0	109.0	102.6	107.8	102.5	108.0	77.3	78.8
J - Information and communication	119.7	121.6	124.5	104.9	123.1	104.3	124.7	103.7	78.0	74.2
K - Financial and insurance activities	121.6	121.2	118.7	122.1	117.1	120.4	117.4	120.4	81.1	83.9
L - Real estate activities	125.7	127.4	162.1	118.6	162.1	118.6	162.1	118.6	---	---
M - Professional, scientific and technical activities	99.0	99.2	100.6	113.2	98.7	104.8	98.7	105.4	72.5	74.4
N - Administrative and support service activities	103.8	104.5	101.0	117.4	100.6	116.8	100.6	116.9	---	78.5
O - Public administration and defense	92.4	92.4	92.4	85.9	92.4	85.9	92.4	85.9	---	---
P - Education	117.5	117.5	117.5	117.5	---	117.3	---	117.3	---	---
Q - Human health and social work activities	79.9	79.9	80.6	79.9	80.6	79.9	80.6	79.9	---	---
R - Arts, entertainment and recreation	103.3	107.0	77.6	120.3	77.5	119.5	77.5	119.6	---	80.7
S - Other service activities	124.1	128.9	106.7	140.6	103.2	138.4	105.7	138.4	86.3	76.6
Total	---	---	108.4	113.2	105.2	110.5	110.0	113.4	86.9	77.6

Unit: Yen per dollar (JPY/USD). Source: Our estimates. Note: Industry classification is based on the ISIC Rev.4. The market exchange rate in 2011 is 79.8 yen to the dollar on annual average.

In Agriculture, forestry and fishing, the PPP for domestic outputs was 197.7 yen per dollar in 2011, indicating the Japanese producers are considerably inferior in price competitiveness of agricultural products compared to producers in the U.S., although some gaps may be explained by unobserved difference in quality.[20] This price gap in output is much larger than the purchaser-price PPP of composite products for household use (133.5 yen per dollar), again emphasizing the importance of accounting for the contribution of imports and margins. In summary, in order to compare price competitiveness by industry, these cases show that it is indispensable to estimate the differentials in output prices, which can differ considerably from the purchaser-price PPPs of composite products that are more readily available in the data. Figure 6 presents the PPPs for industry outputs (excluding the net indirect taxes), $\mathbf{PPP}_j^{d*}$, based on 173 industry classification in 2011. There are large differences across ISIC groups in Table 4. Most estimates of industry PPPs classified in A. Agriculture, forestry and fishery (industries 1-12) are over 150 yen per dollar, with three exceptions of 6.Other non-edible crops (76.1 yen per dollar), 10.Agricultural and forestry services (111.0), and 12.Fishing (71.9).

In manufacturing except foods (industries 33-123), even with the highly appreciated exchange rate (79.8 yen per dollar) in 2011, Japanese industries were still superior in price competitiveness in 25 of 91 industries. The number of industries with superior competitiveness increased to 59 under the current exchange rate (110.6 yen per dollar), indicating the importance of exchange rate movements in determining international competitiveness.[21]

In services (industries 124-173) presented in Figure 6, Japanese industries were inferior in price competitiveness in 44 of 50 industries in 2011, most notably in 129.Gas distribution (the PPP for output is 303.2 yen per dollar), 144.Warehousing and storage (289.1), 128.Electric power generation and distribution (188.9), 136.Real estate (162.1), 170.Barber shops (155.3), and 142.Air transportation (151.0). If these same relative prices held at the current nominal exchange rate (110.6 yen per dollar), 24 of 50 industries would be superior in price competitiveness. In fact, there are some service industries in which Japan already has significant pricing advantages compared to the U.S., like 160.Other rental and leasing (the PPP for output is 54.1 yen per dollar), 161.Motor vehicle repair (64.3), and 145.Travel arrangement services (74.9).

The declines in PPP for outputs over time in some service industries are significant. In the PPPs for service outputs in 1990 and 2005 estimated in Nomura and Miyagawa (1999) and (2015) respectively, Japan's price competitiveness was evaluated to be inferior to the U.S. in 91% (43 of 47 service industries) in 1990 and in 70% (35 of 50) in 2005, using the current exchange rate (110.6 yen per dollar). Our current estimates show that 52% (26 of 50) were inferior in 2011. The PPPs of 74% (37 of 50 service industries) declined from 2005 to 2011.

To try to relate this to industry fundamentals, Figure 5 plots the changes in the PPPs for service outputs between 2005 and 2011 against the two-country average share of compensation of employees (COE) in gross output for the service industries in 2011. One hypothesis is that the fall in labor prices in Japan relative to the U.S. (Figure 3) enabled relatively labor-intensive service

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[20] Note that the difference in the products observed at our elementary level in Section 3.2 is considered. The purchaser's price PPPs for Agriculture, forestry and fishing are much higher in industry use than that in household use in Table 4. This seems contradict that Japan's rice price is much higher than that in the U.S. However, this is consistent with that households are defined in Japan's IOT to consume rice not directly from agricultural sector, but from food manufacturing sector as polished rice.

[21] We do not have a full general equilibrium model that determines how prices react to changes in policy that also results in changes to the nominal exchange rate. Therefore, our competitiveness measures reflect the joint determination of the prices and exchange rate, but we are not able to assess how prices would change if the exchange rate changes.

producers in Japan to charge lower prices to purchasers in 2011 than in 2005. This would manifest as a downward sloping line between the change in the PPP level between 2011 and 2005 and the COE share. Figure 5 shows very limited evidence of this. For example, 159. Motor vehicle rental and leasing and 160.Other rental and leasing in Japan had a low labor share, but improved price competitiveness. Furthermore, a significant share of the PPPs for services increased in 2011 and 2005. Japan's output price in 153.Veterinary service, which has labor cost of over 40% of nominal output increased from 2005 to 2011 relative U.S. production prices. These observations suggest two conclusions: labor costs alone cannot account for the overall decline in the PPPs for services and using the cost approach to measuring PPPs for outputs based on input costs (for example using the labor PPP to estimate the output PPP) likely leads to inappropriate estimates of the output PPPs.

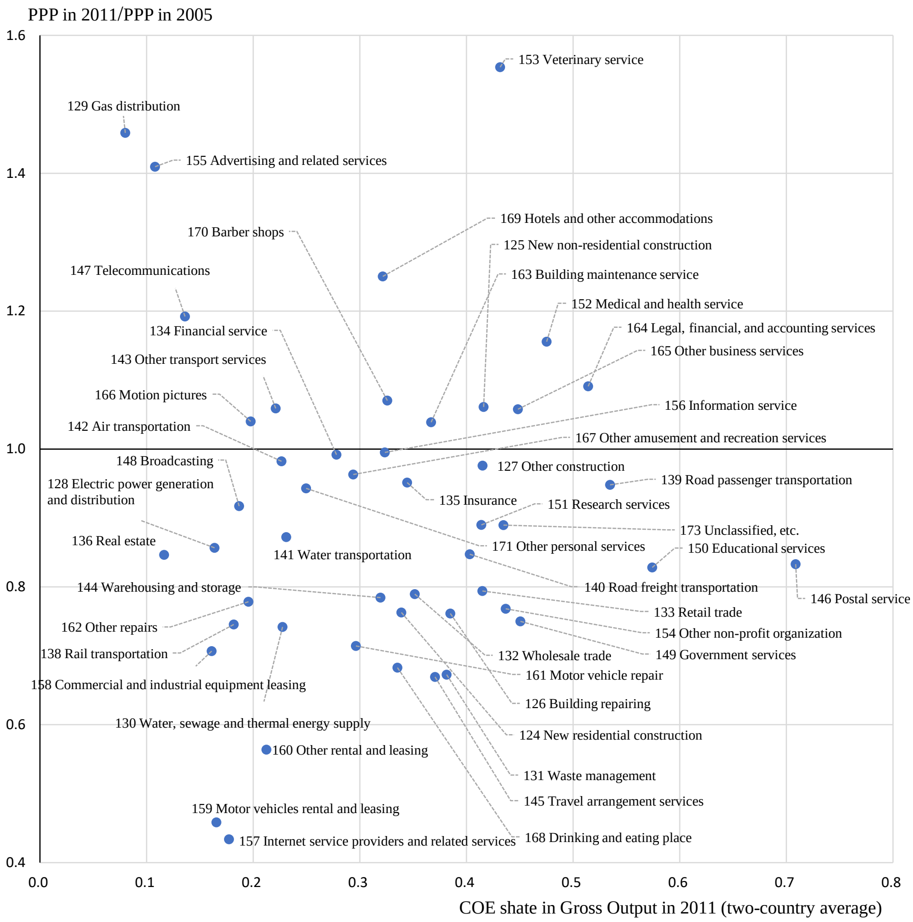

Figure 5: Changes in PPPs for Service Outputs from 2005 to 2011

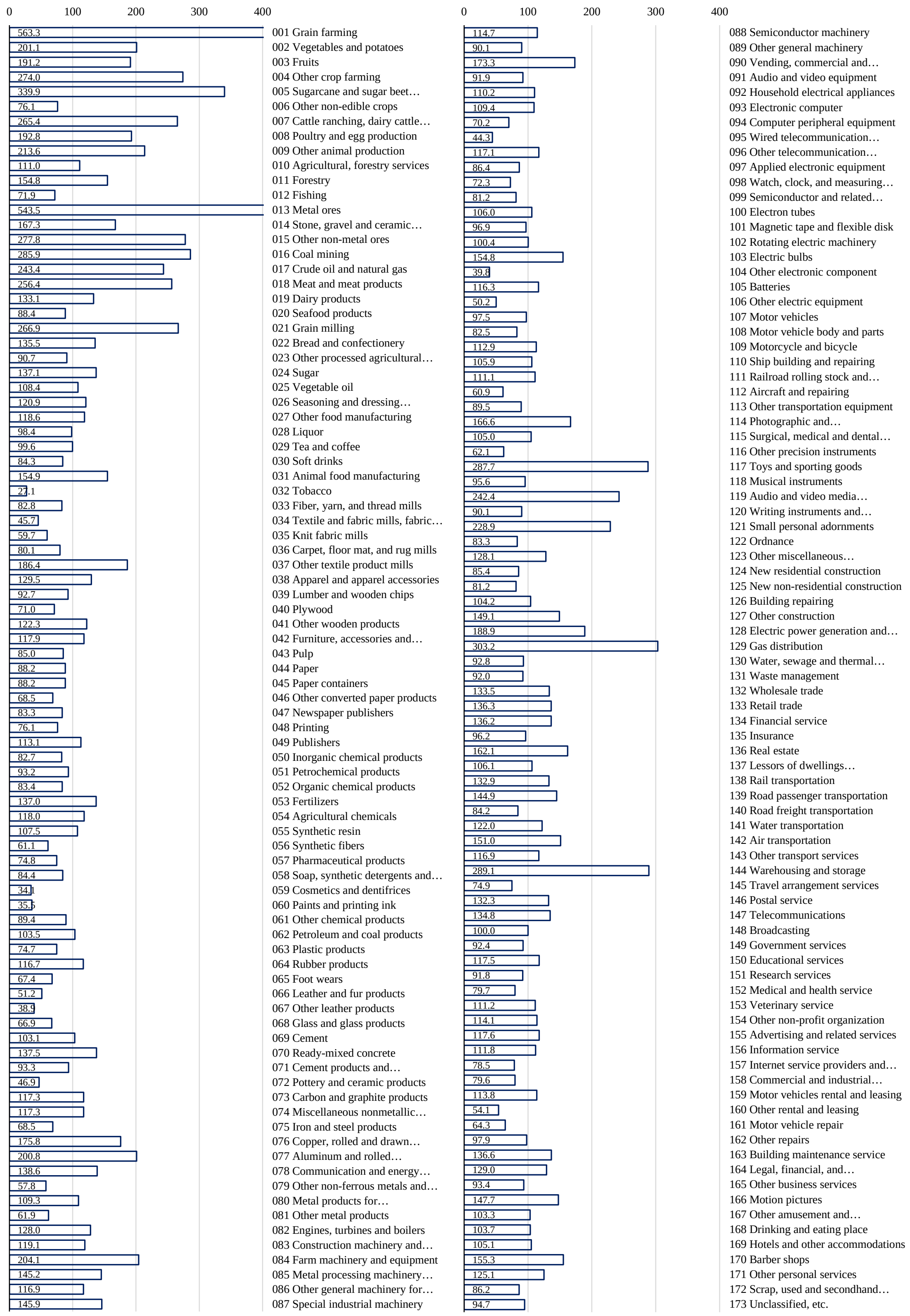

Figure 6: PPPs for Industry Outputs in 2011

5 Conclusion

This paper provides new benchmark estimates of Japan-US industry-level price differentials for 2011, based on a price accounting model that links prices between the U.S. and Japan and maps available price data to model consistent industry prices. Price comparisons among countries at the industry level is a challenging task, but constructing measures that are conceptually appropriate is indispensable for evaluating efficiency in production systems and international competitiveness on world markets.

We find that the PPP for GDP, derived from aggregating our estimates of the PPPs for industry-GDP at basic prices, is 109.0 yen per dollar in 2011. In 2011, the Yen appreciated to a historic high of 79.8 yen per dollar. Under the current exchange rate of 110.6 yen per dollar as of the beginning of July 2018, we estimate that Japanese industries are superior in price competitiveness in 59 of 91 industries in the manufacturing sector except foods and in 26 of 50 industries in service sector in comparison to U.S. producers. Some Japanese producers are considerably inferior in price competitiveness in comparison to the U.S; in particular, the energy industries providing electricity, gas, and heat, and industries producing most agricultural products.

The accuracy of the estimated PPPs for industry outputs depends critically on the quality of the data on margin rates and the other related parameters. In addition, our analysis of the PPPs of service outputs and their relation to labor inputs indicates that the cost approach to measuring PPPs for outputs likely leads to inaccurate estimates. Employing simplifying assumptions on the relationship between prices likely leads to significant biases and incorrect measures of international competitive position. This indicates that improving the measurement of price differentials and the related parameters at the detailed product level is the best path forward in building conceptually consistent and precise price competitiveness measures across industries and countries.

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Appendix: Bilateral Price Model

1 Producer's Prices

To construct the price model describing the production system in Figure 1, we use the following notation for product *i*:

$p^{d}_{k,i}$ Prices of products produced in country *k* at producer's prices in currency of country *k*,

$p^{d}_{kE,i}$ Prices of products produced in country *k*, purchased by exogenous economies at producer's prices (excluding net indirect taxes on products and consumption tax) in currency of country *k*,

$p^{d,l}_{k,i}$ Prices of products produced in country *k*, purchased by industries (*I*) or household (*H*) in country *k* at producers' prices in currency of country *k*, (If *l* = *I*, the product is purchased by industries for intermediate uses or investment, and the price includes net indirect taxes on products. If *l* = *H*, the product is purchased by household for final consumption, and the price includes net indirect taxes on products and consumption tax.),

$p^{d,l}_{kk',i}$ Prices of products produced in country *k*, purchased by industries (*I*) or household (*H*) in country *k'* at producers' prices in currency of country *k*, (If *l* = *I*, the product is purchased by industries. If *l* = *H*, the product is purchased by household. The both prices exclude net indirect taxes on products.),

$p^{m,l}_{kk',i}$ Prices of imports from country *k*, purchased by industries (*I*) or household (*H*) in *k'*-country at the CIF prices plus tariff and net indirect taxes on imports in currency of country *k'*, (If *l* = *I*, the product is purchased by industries and the price excludes consumption tax. If *l* = *H*, the product is purchased by household and the price includes consumption tax.),

$p^{fob,l}_{kk',i}$ Prices of imports from country *k*, purchased by industries (*I*) or household (*H*) in country *k'* at the FOB prices in currency of country *k*, (If *l* = *I*, the product is purchased by industries. If *l* = *H*, the product is purchased by household.)

$p^{c,l}_{k,i}$ Prices of composite products (domestic products plus imports), purchased by industries (*I*) or household (*H*) in country *k* at producers' prices in currency of country *k*, (If *l* = *I*, the product is purchased by industries and the price includes net indirect taxes on products. If *l* = *H*, the product is purchased by household and the price includes net indirect taxes on products and consumption tax.),

$X_{kk',ij}$ Volumes of products produced in country *k* and purchased by sector *j* in country *k'*,

$X_{k,i}$ Volumes of products produced in country *k*,

$\tau^{f}_{kk',i}$ Rates of freight and insurance for imports from country *k*, purchased in country *k'*,

$\tau^{r}_{kk',i}$ Rates of tariff for imports from country *k*, purchased in country *k'*,

$\tau^{l}_{k,i}$ Rates of net indirect taxes on products in country *k* for industries (*I*) or household (*H*), (If $l = I$, the rate is for industries and excludes consumption tax.[22] If $l = H$, the rate is for households and includes consumption tax.),

$\tau_{k,i}^{d}$ The effective rates of indirect taxes in country k,

$TX_{k,i}^{d}$ The amount of indirect taxes of domestic products in country k

$e_{k/k'}$ Exchange rate of currency of country k against the currency of country k', (e.g. Japan's exchange rate to the U.S. dollar is $e_{J/U}$)

$T_{k,i}^{e,l}$ Transportation service input for one unit of exports in country k, (If $l = I$, the service is input for industries. If $l = H$, the service is input for households.),

$W_{k,i}^{e,l}$ Trade service input for one unit of exports in country k, (If $l = I$, the service is input for industries. If $l = H$, the service is input for households.),

$m_{k,i}^{T,e,l}$ Rates of transportation cost (T) of products in country k for exported products, (If $l = I$, the rate is for industries. If $l = H$, the rate is for households.),

$m_{k,i}^{W,e,l}$ Rates of trade margin (W) of products in country k for exported products, (If $l = I$, the rate is for industries. If $l = H$, the rate is for households.).

We begin with clarifying the treatment of indirect taxes in our model. In Japan's transactions of Figure 1, only households pay the consumption tax. Therefore, we distinguish between the producer's prices of the domestically produced outputs, $p_{J,i}^{d,I}$ (for industry) and $p_{J,i}^{d,H}$ (for household).[23] The rates of net indirect taxes on products for industries and households are also distinguished as $\tau_{J,i}^{I}$ and $\tau_{J,i}^{H}$, respectively. As for the prices of exports, since both the consumption tax and other indirect taxes on products are deductible, Japan's export prices to the U.S. ($p_{JU,i}^{d,H}$ and $p_{JU,i}^{d,I}$) are formulated as:

(1) $p_{JU,i}^{d,l} = p_{J,i}^{d,l} / (1 + \tau_{J,i}^{l}) \qquad (k = J, U \ \text{ and } \ l = I, H).$

On the other hand, the Japanese producer's price $p_{J,i}^{d}$ is defined as a composite of the producer's prices across all types of demand. The total of the domestic indirect taxes (excluding indirect tax for imported products) of product i is described as:

(2) $$TX_{J,i}^{d} = \left(\frac{\tau_{J,i}^{I}}{1+\tau_{J,i}^{I}}\right) p_{J,i}^{d,I} \sum_{j \in I} X_{JJ,ij} + \left(\frac{\tau_{J,i}^{H}}{1+\tau_{J,i}^{H}}\right) p_{J,i}^{d,H} X_{JJ,iH}.$$

The first term on the right-hand side represents the amount of other indirect tax paid by industries (I) and the second term is the amount of the consumption tax and other indirect tax paid by households (H). Based on $TX_{J,i}^{d}$, the effective rate of indirect taxes for domestic product i in Japan is defined as:

(3) $\tau_{J,i}^{d} = TX_{J,i}^{d} / (p_{J,i}^{d} X_{J,i} - TX_{J,i}^{d}),$

where $p_{J,i}^{d} X_{J,i}$ is gross output in Japan. Using $\tau_{J,i}^{d}$, Japan's export price to the exogenous economies is formulated as:

[22] The consumption tax on the products purchased by the producers who produce consumption tax exempt products (e.g. medical care) are non-deductible. We describe that the consumption tax is excluded from $\tau_{k,i}^{I}$ in the description of our price model for simplicity, but some non-deductible consumption taxes in domestic final demand excluding household consumption (Z) are considered in our actual estimation.

[23] In addition to the differences in indirect taxes for industry and household uses, our price model permits differences in the basic prices for industry and household uses, reflecting the observed price differentials in different demand types of the product which are classified to the same group. These may indicate that the types or qualities of the same product at the more detail level are different, but we treat them as if they were additive for simplicity of our price model.

(4) $p^{d}_{JE,i} = p^{d}_{J,i} / (1 + \tau^{d}_{J,i})$.

In the case of exports to exogenous economies, that is Equation (4), we do not distinguish between exports to industry and households due to data constraints, unlike the bilateral trade prices between Japan and the U.S. which do account for price differences between households and industry. Analogous Equations (1) to (4) also hold for the U.S.

The IOT in Figure 1 imposes that the value of output is balanced across uses:

(5) $p^{d}_{J,i} X_{J,i} = p^{d,I}_{J,i} \sum_{j \in I} X_{JJ,ij} + p^{d,I}_{JU,i} \sum_{j \in I} X_{JU,ij} + p^{d,H}_{J,i} X_{JJ,iH} + p^{d,H}_{JU,i} X_{JU,iH} + p^{d}_{JE,i} X_{JE,i}$

The first term on the right-hand side represents industry uses (intermediate uses and investment) in Japan, the second term is the imports by the U.S. industries for the intermediate uses, the third term is the household uses in Japan, the fourth term is the imports by the U.S. households, and the final term accounts for exports to exogenous economies.

Corresponding to the Isard-type BIOT in Figure 1, we define the Chenery-Moses-type IOT (the competitive import type IOT) for both Japan and the U.S. (Chenery, 1953; Moses, 1955). Figure A1 represents this table for Japan (the table for the U.S. is defined analogously).

	Intermediate inputs (N)	Household consumption (C)	Government consumption & Gross capital formation (Z)	Exports (E)	(–)Imports (M)	Gross output (X)
Intermediate inputs	$p^{c,I}_{J,i} X_{J,ij}$	$p^{c,H}_{J,i} X_{J,iH}$	$p^{c,I}_{J,i} X_{JJ,iZ}$	$\sum_{j \in I} p^{d,I}_{JU,i} X_{JU,ij} + p^{d,H}_{JU,i} X_{JU,iH} + p^{d}_{JE,i} X_{JE,iE}$	$\sum_{k=U,E} (\sum_{j \in I} p^{m,I}_{kJ,i} X_{kJ,ij} + p^{m,H}_{kJ,i} X_{kJ,iH})$	$p^{d}_{J,i} X_{J,i}$
Value added	$VA_{J,j}$					
Gross output	$p^{d}_{J,j} X_{J,j}$					

Figure A1: Japanese Input-Output Table (the Chenery-Moses-Type)

Based on the Chenery-Moses-type input-output framework in Figure A1, the output balance including Japan's uses of imports at current prices is described as:

(6)
$$p^{d}_{J,i} X_{J,i} = \sum_{j \in I} p^{c,I}_{J,i} X_{J,ij} + p^{c,H}_{J,i} X_{J,iH} + \left(\sum_{j \in I} p^{d,I}_{JU,i} X_{JU,ij} + p^{d,H}_{JU,i} X_{JU,iH} + p^{d}_{JE,i} X_{JE,i} \right) - \sum_{k=U,E} \left(\sum_{j \in I} p^{m,I}_{kJ,i} X_{kJ,ij} + p^{m,H}_{kJ,i} X_{kJ,iH} \right),$$

where $X_{J,ij}$ is the domestic demand of product *i* by sector *j* in Japan including both domestic products and imports, and $p^{c,I}_{J,i}$ stands for the corresponding prices of the composite products (of domestically produced products plus imports). These demand prices are embedded in the accounting identity as:

(7) $p^{c,l}_{J,i} X_{J,il} = p^{d,l}_{J,i} X_{JJ,il} + p^{m,l}_{UJ,i} X_{UJ,il} + p^{m,l}_{EJ,i} X_{EJ,il}$ $\quad (l = I, H)$.

The outputs at constant prices are assumed to be additive among the different demand types;

(8)
$$\begin{aligned} X_{J,i} &= \sum_{j \in D} X_{JJ,ij} + \sum_{j \in D} X_{JU,ij} + X_{JE,i} \\ &= \sum_{j \in D} X_{J,ij} + \sum_{j \in D} X_{JU,ij} + X_{JE,i} - \sum_{j \in D} X_{UJ,ij} - \sum_{j \in D} X_{EJ,ij}. \end{aligned}$$

The former equation corresponds with the nominal balance of Equation (5) and the latter corresponds to Equation (6). We also assume additivity among domestic inputs and imports:

(9) $X_{J,ij} = X_{JJ,ij} + X_{UJ,ij} + X_{EJ,ij}$ $\quad (j \in D)$.

We define the output share at constant prices:

(10) $w_{Jk,i}^{d,l} = \sum_{j\in l} X_{Jk,ij}/X_{J,i}$ $(k = J, U, l = I, H)$ and $w_{JE,i}^{d} = X_{JE,i}/X_{J,i}$,

where $w_{JJ,i}^{d,I} + w_{JU,i}^{d,I} + w_{JJ,i}^{d,H} + w_{JU,i}^{d,H} + w_{JE,i}^{d} = 1$. Based on Equations (5) to (10), Japan's output price of product *i* is described as:

(11) $p_{J,i}^{d} = p_{J,i}^{d,I} w_{JJ,i}^{d,I} + p_{JU,i}^{d,I} w_{JU,i}^{d,I} + p_{J,i}^{d,H} w_{JJ,i}^{d,H} + p_{JU,i}^{d,H} w_{JU,i}^{d,H} + p_{JE,i}^{d} w_{JE,i}^{d}$.

By substituting Equations (1) and (4) into Equation (11), we obtain:

(12) $p_{J,i}^{d} = \left\{ p_{J,i}^{d,I}\left(w_{JJ,i}^{d,I} + \frac{w_{JU,i}^{d,I}}{1+\tau_{J,i}^{I}}\right) + p_{J,i}^{d,H}\left(w_{JJ,i}^{d,H} + \frac{w_{JU,i}^{d,H}}{1+\tau_{J,i}^{I}}\right)\right\} \Big/ \left(1 - \frac{w_{JE,i}^{d}}{1+\tau_{J,i}^{d}}\right)$.

Thus Japan's output price, $p_{J,i}^{d}$, is measured using $p_{J,i}^{d,I}$ and $p_{J,i}^{d,H}$, the output shares, and the rates of indirect taxes.

On the other hand, in order to clarify the relationship between the U.S. producer's price $p_{UJ,i}^{d,l}$ for sales to Japan, and Japan's import prices from the U.S., $p_{UJ,i}^{m,l}$, we describe the U.S. FOB price as:

(13) $p_{UJ,i}^{fob,l} = p_{UJ,i}^{d,l} + p_{UJ,T}^{d,l} T_{U,i}^{e} + p_{UJ,W}^{d,l} W_{U,i}^{e}$ $(l = I, H)$,

where $p_{UJ,T}^{d,l}$ and $p_{UJ,W}^{d,l}$ are the prices of U.S. transportation and trade sectors for the exports to Japan, respectively, and $T_{U,i}^{e,l}$ and $W_{U,i}^{e,l}$ are the volumes of transportation and trade services for one unit of exports of product *i* required in the U.S. We define the rate of transportation cost $m_{U,i}^{T,E,l}$ and the rate of trade margin $m_{U,i}^{W,e,l}$ for exported products as,

(14) $m_{U,i}^{T,e,l} = p_{UJ,T}^{d,l} T_{U,i}^{e}/p_{UJ,i}^{fob,l}$ and $m_{U,i}^{W,e,l} = p_{UJ,W}^{d,l} W_{U,i}^{e}/p_{UJ,i}^{fob,l}$ $(l = I, H)$,

respectively. From Equation (13) and (14), the FOB prices for households and industries are represented as:

(15) $p_{UJ,i}^{fob,l} = p_{UJ,i}^{d,l} \; /(1 - m_{U,i}^{T,e,l} - m_{U,i}^{W,e,l})$ $(l = I, H)$.

The prices of imports for industry and household uses, $p_{UJ,i}^{m,I}$ and $p_{UJ,i}^{m,H}$, are calculated by adding the custom duty and indirect taxes on products to the CIF price as:

(16) $p_{UJ,i}^{m,l} = e_{J/U}(1 + \tau_{J,i}^{l})(1 + \tau_{UJ,i}^{r})(1 + \tau_{UJ,i}^{f}) p_{UJ,i}^{fob,l} = e_{J/U}\,\omega_{UJ,i}^{l} p_{UJ,i}^{d,l}$ $(l = I, H)$,

where $e_{J/U}$ is the exchange rate of the Japanese yen against the U.S. dollar, $\tau_{UJ,i}^{f}$ and $\tau_{UJ,i}^{r}$ are the rates of the international freight and insurance and the tariff for one unit of product *i* imported from the U.S. to Japan, respectively, and $\omega_{kk',i}^{l}$ is defined as $(1 + \tau_{k',i}^{l})(1 + \tau_{kk',i}^{r})(1 + \tau_{kk',i}^{f})/(1 - m_{U,i}^{T,e,l} - m_{U,i}^{W,e,l})$ for $l = I, H$ for notational simplicity.[24]

Meanwhile, the volume share of demand of domestic product and imported product is defined as:

(17) $w_{kJ,i}^{c,l} = \sum_{j\in l} X_{kJ,ij}/\sum_{j\in l} X_{J,ij}$ $(k = J, U, E$ and $l = I, H)$,

where $w_{JJ,i}^{c,l} + w_{UJ,i}^{c,l} + w_{EJ,i}^{c,l} = 1$ for $l = I, H$. By assigning Equations (16) and (17) to Equation (7), we obtain:

(18) $p_{J,i}^{c,l} = p_{J,i}^{d,l} w_{JJ,i}^{c,l} + e_{J/U}\,\omega_{UJ,i}^{l} p_{UJ,i}^{d,l} w_{UJ,i}^{c,l} + p_{EJ,i}^{m,l} w_{EJ,i}^{c,l}$ $(l = I, H)$.

Similarly, the demand prices in the U.S. are shown as:

(19) $p_{U,i}^{c,l} = p_{U,i}^{d,l} w_{UU,i}^{c,l} + \omega_{JU,i}^{l} p_{JU,i}^{d,l} w_{JU,i}^{c,l}/e_{J/U} + p_{EU,i}^{m,l} w_{EU,i}^{c,l}$ $(l = I, H)$.

Equations (18) and (19) describe the price relationship between the producer's prices of Japan and

[24] The data $\tau_{UJ,i}^{r}$ is based on our extended 2011 Japan-US BIOT and the data $\tau_{UJ,i}^{f}$ is assumed to be identical with the estimates in the 2005 Japan-US BIOT by METI.

the U.S. through bilateral trade.

Based on the definitions of our prices, we define several price level indices (PLI) between Japan and the U.S. as,

$$(20)\quad \mathbf{P}^{d}_{J/U,i} = \frac{p^{d}_{J,i}}{e_{J/U}p^{d}_{U,i}}, \mathbf{P}^{d,l}_{J/U,i} = \frac{p^{d,l}_{J,i}}{e_{J/U}p^{d,l}_{U,i}}, \mathbf{P}^{c,l}_{J/U,i} = \frac{p^{c,l}_{J,i}}{e_{J/U}p^{c,l}_{U,i}} \qquad (l = I, H),$$

where $\mathbf{P}^{d}_{J/U,i}$ is the PLI of output at producer's price of product *i* between Japan and the U.S. The second equation describes the definition of the PLIs of output at producer's price for households and for industries, $\mathbf{P}^{d,H}_{J/U,i}$ and $\mathbf{P}^{d,I}_{J/U,i}$, respectively. The third equation describes the PLIs of demand prices at producer's price, $\mathbf{P}^{c,H}_{J/U,i}$ and $\mathbf{P}^{c,I}_{J/U,i}$, respectively. By substituting Equations (18) and (19), into (20), the Japan-US PLI of domestic demand prices for households and industries are obtained as follows:

$$(21)\quad \mathbf{P}^{c,l}_{J/U,i} = \frac{\mathbf{P}^{d,l}_{J/U,i}w^{c,l}_{JJ,i} + \omega^{l}_{UJ,i}w^{c,l}_{UJ,i}/(1+\tau^{l}_{U,i}) + \mathbf{P}^{m,l}_{EJ/U,i}w^{c,l}_{EJ,i}}{w^{c,l}_{UU,i} + \mathbf{P}^{d,l}_{J/U,i}\omega^{l}_{JU,i}w^{c,l}_{JU,i}/(1+\tau^{l}_{J,i}) + \mathbf{P}^{m,l}_{EU/U,i}w^{c,l}_{EU,i}} \qquad (l = I, H).$$

$\mathbf{P}^{m,l}_{Ek/U,i}$ is the PLI of the imports from exogenous economies to Japan or the U.S., relative to the domestic producer's prices in the U.S. These imports PLIs are defined as:

$$(22)\quad \mathbf{P}^{m,l}_{EJ/U,i} = \frac{p^{m,l}_{EJ,i}}{e_{J/U}\, p^{d,l}_{U,i}} \text{ and } \mathbf{P}^{m,l}_{EU/U,i} = \frac{p^{m,l}_{EU,i}}{p^{d,l}_{U,i}} \qquad (l = I, H).$$

The import price indices for Japan and the U.S., $p^{m,l}_{EJ/U,i}$ and $p^{m,l}_{EU/U,i}$ respectively, are endogenous in the model and determined by the sub model, as presented in the subsequent section. From Equation (21), we obtain:

$$(23)\quad \mathbf{P}^{d,l}_{J/U,i} = \frac{\omega^{l}_{UJ,i}w^{c,l}_{UJ,i}/(1+\tau^{l}_{U,i}) + \mathbf{P}^{m,l}_{EJ/U,i}w^{c,l}_{EJ,i} - \mathbf{P}^{c,l}_{J/U,i}\left(w^{c,l}_{UU,i} + \mathbf{P}^{m,l}_{EU/U,i}w^{c,l}_{EU,i}\right)}{\mathbf{P}^{c,l}_{J/U,i}\omega^{l}_{JU,i}w^{c,l}_{JU,i}/(1+\tau^{l}_{J,i}) - w^{c,l}_{JJ,i}} \qquad (l = I, H).$$

If the PLIs of the demand prices and the imports from exogenous economies are available as data, the PLI of output at producer's price are measured by this equation.

When the PLIs for $\mathbf{P}^{d,I}_{J/U,i}$ and $\mathbf{P}^{d,H}_{J/U,i}$ (price level indexes for industry and household) are available in the data, we can measure the PLI of domestic outputs, $\mathbf{P}^{d}_{J/U,i}$, based on Equation (12) as:

$$(24)\quad \mathbf{P}^{d}_{J/U,i} = \left\{\mathbf{P}^{d,I}_{J/U,i}\left(\frac{p^{d,I}_{U,i}w^{d,I}_{JJ,i}}{p^{d}_{U,i}} + \frac{p^{d,I}_{U,i}w^{d,I}_{JU,i}}{(1+\tau^{I}_{J,i})p^{d}_{U,i}}\right) + \mathbf{P}^{d,H}_{J/U,i}\left(\frac{p^{d,H}_{U,i}w^{d,H}_{JJ,i}}{p^{d}_{U,i}} + \frac{p^{d,H}_{U,i}w^{d,H}_{JU,i}}{\left(1+\tau^{H}_{J,i}\right)p^{d}_{U,i}}\right)\right\} \Big/ \left(1 - \frac{w^{d}_{JE,i}}{1+\tau^{d}_{J,i}}\right).$$

In this equation, $\mathbf{P}^{d}_{J/U,i}$ is defined including the indirect taxes. Since our framework is based on METI's symmetric BIOT, this product-PLI is identical to the industry-PLI ($\mathbf{P}^{d}_{J/U,i} = \mathbf{P}^{d}_{J/U,j}$). To enable us to compare the prices and volumes of outputs, the PLI of *j*-industry outputs at basic prices $\mathbf{P}^{d*}_{J/U,j}$ as:

$$(25)\quad \mathbf{P}^{d*}_{J/U,i} = \mathbf{P}^{d}_{J/U,i}\,\frac{1+\tau^{d}_{U,i}}{1+\tau^{d}_{J,i}}.$$

In our study, only the Japan-US differences in the indirect taxes on the consumption of liquor, tobacco, and gasoline are taken into account.

2 Purchaser's Prices

The first section of the Appendix described the price model based on producer's prices. However, the PPP data in the main data sources are measured at purchaser's prices. In this section, we describe the relationship between the producer's prices and purchaser's prices. Some additional notation is required:

$p_{k,i}^{pd,l}$ Prices of products in country *k*, purchased by industries (*I*) or household (*H*) in country *k* at purchasers' prices in currency of country *k*, (If *l* = *I*, the product is purchased by industries for intermediate uses or investment. If *l* = *H*, the product is purchased by household for final consumption.),

$p_{kk',i}^{pd,l}$ Prices of products produced in country *k*, purchased by industries (*I*) or household (*H*) in country *k'* at purchasers' prices in currency of country *k*, (If *l* = *I*, the product is purchased by industries. If *l* = *H*, the product is purchased by household.),

$p_{kk',i}^{pm,l}$ Prices of imports from country *k*, purchased by industries (*I*) or household (*H*) in country *k'* at purchasers' prices in currency of country *k'*, (If *l* = *I*, the product is purchased by industries. If *l* = *H*, the product is purchased by household.),

$T_{k,i}^{l}$ Transportation service input for one unit of imported and domestic products in country *k*, (If *l* = *I*, the service is input for industries. If *l* = *H*, the service is input for households.),

$W_{k,i}^{d,l}$ Trade service input for one unit of domestic products in country *k*, (If *l* = *I*, the service is input for industries. If *l* = *H*, the service is input for households.),

$W_{k,i}^{m,l}$ Trade service input for one unit of imports in country *k*, (If *l* = *I*, the service is input for industries. If *l* = *H*, the service is input for households.),

$m_{k,i}^{T,l}$ Rates of transportation cost (*T*) of products in country *k* for imported and domestic products, (If *l* = *I*, the rate is for industries. If *l* = *H*, the rate is for households.)

$m_{k,i}^{W,l}$ Rates of trade margin (*W*) of products in *k*-country for imported and domestic products, (If *l* = *I*, the rate is for industries. If *l* = *H*, the rate is for households.)

$m_{k,i}^{W,d,l}$ Rates of trade margin (*W*) of products in country *k* for domestic products, (If *l* = *I*, the rate is for industries. If *l* = *H*, the rate is for households.)

$m_{k,i}^{W,m,l}$ Rates of trade margin (*W*) of products in country *k* for imported products, (If *l* = *I*, the rate is for industries. If *l* = *H*, the rate is for households.)

The purchaser's price paid by industries and households is defined as the sum of the producer-price value, the transportation cost, and the trade margin as:

(26) $$p_{J,i}^{pd,l} = p_{J,i}^{d,l} + p_{J,T}^{d,l} T_{J,i}^{l} + p_{J,W}^{d,l} W_{J,i}^{d,l} \qquad (l = I, H),$$

where $p_{J,T}^{d,l}$ and $p_{J,W}^{d,l}$ are the output prices of the transportation and trade services in Japan and $T_{J,i}^{l}$ and $W_{J,i}^{d,l}$ are the transportation and the trade services required for one unit of product *i*. In our model, since the trade margin rates are distinguished for domestic products and imports, the superscript "d" is added for the trade margin. The rates of transportation cost and trade margin to the purchaser's prices of domestic products are defined as:

(27) $$m_{J,i}^{T,l} = p_{J,T}^{d,l} T_{J,i}^{l} / p_{J,i}^{pd,l} \text{ and } m_{J,i}^{W,d,l} = p_{J,W}^{d,l} W_{J,i}^{d,l} / p_{J,i}^{pd,l} \quad (l = I, H),$$

respectively, for each of industry or household use. Based on Equations (26) and (27), the relationship between producer's prices and purchaser's prices is given by:

(28) $p_{J,i}^{d,l} = p_{J,i}^{pd,l}\left(1 - m_{J,i}^{T,l} - m_{J,i}^{W,d,l}\right) \qquad (l = I, H).$

Analogous equations exist for the U.S. The PLI in purchaser's prices for domestic products is described as:

(29) $\mathbf{P}_{J/U,i}^{pd,l} = \frac{p_{J,i}^{pd,l}}{e_{J/U}\, p_{U,i}^{pd,l}} = \mathbf{P}_{J/U,i}^{d,l} \frac{\left(1-m_{U,i}^{T,l}-m_{U,i}^{W,d,l}\right)}{\left(1-m_{J,i}^{T,l}-m_{J,i}^{W,d,l}\right)} \qquad (l = I, H).$

This equation gives the relationship between the producer-price PLI and the purchaser-price PLI of domestic products.

The PLI for composite demand, which reflects the prices of both imports and its domestic counterpart, is represented as:

(30) $\mathbf{P}_{J/U,i}^{pc,l} = \frac{p_{J,i}^{pc,l}}{e_{J/U}\, p_{U,i}^{pc,l}} = \mathbf{P}_{J/U,i}^{c,l} \frac{\left(1-m_{U,i}^{T,l}-m_{U,i}^{W,l}\right)}{\left(1-m_{J,i}^{T,l}-m_{J,i}^{W,l}\right)} \qquad (l = I, H).$

The rate of transportation cost for the component of imports is the same as that for the domestic products. Thus the same rates of $m_{J,i}^{T,l}$ and $m_{U,i}^{T,l}$ are applied in Equations (29) and (30). On the other hand, the rate of domestic trade margin for imports $m_{k,i}^{W,m,l}$ is different from that for domestic products $m_{k,i}^{W,d,l}$ in our model. Therefore, equation (30) is described using, $m_{J,i}^{W,l}$ and $m_{U,i}^{W,l}$, which are the rates of trade margin for composite products measured as:

(31) $$m_{k,i}^{W,l} = m_{k,i}^{W,m,l} \textstyle\sum_{j\in l}\left(p_{k'k,i}^{pm,l} X_{k'k,ij} + p_{Ek,i}^{pm,l} X_{Ek,ij}\right) / \textstyle\sum_{j\in l} p_{k,i}^{pc,l} X_{k,ij}$$
$$+ m_{k,i}^{W,d,l} \cdot \textstyle\sum_{j\in l} p_{kk,i}^{pd,l} X_{kk,ij} / \textstyle\sum_{j\in l} p_{k,i}^{pc,l} X_{k,ij} \qquad (kk' = JU \text{ or } UJ \text{ and } l = I, H).$$

Equation (31) indicates that the rate of trade margin for composite products $m_{k,i}^{W,l}$ is measured as a weighted average of $m_{k,i}^{W,m,l}$ and $m_{k,i}^{W,d,l}$, with weights reflecting the nominal value shares evaluated at the purchaser's prices. This study uses the trade margin rates in Nomura and Miyagawa (2018a).

The PLIs, $\mathbf{P}_{J/U,i}^{pc,I}$ and $\mathbf{P}_{J/U,i}^{pc,H}$ in Equation (30), reflect the Japan-US relative price differences for demand prices evaluated by purchaser's prices for industry and household uses, respectively. By isolating the PLI of the products for household use, we are able to define the Japan-US Purchasing Power Parity (PPP) for household consumption by product as:

(32) $\mathbf{PPP}_{J/U,i}^{H} = e_{J/U}\mathbf{P}_{J/U,i}^{pc,H}.$

If the PPP data, $\mathbf{PPP}_{J/U,i}^{H}$, or the purchaser-price PLI, $\mathbf{P}_{J/U,i}^{pc,H}$, on household consumption between Japan and the U.S. are available, we can measure the producer-price PLI of demand prices, $\mathbf{P}_{J/U,i}^{c,H}$, from Equation (30), and then the PLI of domestic products, $\mathbf{P}_{J/U,i}^{d,H}$, can be measured from Equation (23).

3 Import Prices from Exogenous Economies

We next describe the role of import prices from exogenous economies (E) to Japan (J) and the U.S. (U). The estimates of these prices, $p_{EJ,i}^{m,l}$ and $p_{EU,i}^{m,l}$, respectively, are used to infer the producer-price PLI of domestic products $\mathbf{P}_{J/U,i}^{d,l}$ in Equation (23). Some intuition of this is as follows: suppose we observe the price of paper exported from China into Japan, and we observe the final demand price paid for paper in Japan. In our accounting framework, the gap between the two prices reflects the (unmeasured) production price in Japan (after accounting for trade margins and taxes). We define $p^{m,l}_{EJ,i}$ and $p^{m,l}_{EU,i}$ as the combined import prices from exogenous economies:

$$p^{m,l}_{Ek',i} = \sum_k p^{m,l}_{kk',i} v^{m,l}_{kk',i} = \sum_{k \neq R} e_{k'/k} \omega^l_{kk',i} p^{d,l}_{k,i} v^{m,l}_{kk',i} + p^{m,l}_{Rk',i} v^{m,l}_{Rk',i}, \quad (33)$$

$$(l = I, H,\ k = C, G, K, M, W, T, R, \text{and} \quad k' = J \text{ or } U),$$

where the $v^{m,l}_{kk',i}$ stands for the import shares at current prices from country k (the exogenous economies) to country k' (Japan and the U.S.). The sum of the import shares $\sum_k v^{m,l}_{kk',i}$ is one. $p^{m,l}_{Rk',i}$ is the average price of imported goods from the rest of the world (ROW). $\omega^l_{kk',i}$, which is defined in Equation (16), is the combined coefficient to transform the output prices in country k to the import prices in country k' from country k. Since it is difficult to obtain the output prices in country k ($p^{d,l}_{k,i}$) directly from statistical data, we construct the following sub model to determine $p^{d,l}_{k,i}$ in six exogenous economies (k) excluding the ROW.[25]

We describe the demand price (of the composite products) in country k as:

$$p^{c,l}_{k,i} = p^{d,l}_{k,i} v^{c,l}_{kk,i} + \sum_{k \neq k'} e_{k/k'} \omega^l_{k'k,i} p^{d,l}_{k',i} v^{c,l}_{k'k,i} + e_{k/J} \omega^l_{Jk,i} p^{d,l}_{J,i} v^{c,l}_{Jk,i}$$

$$+ e_{k/U} \omega^l_{Uk,i} p^{d,l}_{U,i} v^{cl}_{Uk,i} + p^{m,l}_{Rk,i} v^{c,l}_{Rk',i}, \quad (34)$$

$$(k = C, G, K, M, W, T,\ \ k' = C, G, K, M, W, T, \text{ and } l = I, H).$$

where $v^{c,l}_{kk',i}$ is the demand share of the domestic product and the imported product at current prices from country k to country k'. The sum of the demand shares $\sum_k v^{c,l}_{kk',i}$ is one. In this equation, $p^{d,l}_{k,i}$ in the first and second terms of the right hand are the prices to be determined endogenously in the sub model. The third and fourth terms are the import prices from Japan and the U.S., respectively, whose output prices, $p^{d,l}_{Jk,i}$ and $p^{d,l}_{Uk,i}$, are pre-determined in the main model and are treated as exogenous variables in the sub model. And the final term, $p^{m,l}_{Rk,i}$, is the exogenous prices of imports from the ROW.

In the left-hand side of Equation (34), the demand-price PPPs in country k, $p^{c,l}_{k,i}$, are observed in Eurostat-OECD (2012), METI (2012), or other PPP surveys. The third and fourth terms of the right-hand side of Equation (34), i.e., the output prices in Japan and the U.S., are pre-determined in our main model, as described in the Appendices 1 and 2. The fifth term, i.e., the exogenous prices of imports from the ROW, is also usually unobserved. In this paper, the purchaser's price of imports from the ROW in country k is assumed to be identical with the purchaser's price of the composite product of domestic product in country k and imported products from Japan, the U.S., and other five exogenous countries.[26] For each product i, Equation (34) is defined for the six countries that we consider. Six endogenous variables of domestic output prices in country k, $p^{d,l}_{k,i}$, are determined simultaneously by solving these six linear equations in each product i.

Some iterations are required between the main model and the sub model. By substituting the output prices ($p^{d,l}_{k,i}$) estimated in the sub model for six countries and the exogenous prices of imports

[25] In the sub model, indirect taxes are not considered for simplicity.

[26] The estimates of PPP for outputs are sensitive to the assumption on import prices, in the process to parse the observed price of composite goods into that from domestic supply and that coming from imported goods. In measuring PPPs for 1990 in Nomura and Miyagawa (1999), the similar assumption was applied only for the total of six exogenous economies and the ROW. This induced unreasonable estimates in some products. The explicit treatment of six exogenous economies contributes to reduce these events to be happened. However, in some exceptional cases when the estimated results are unreasonable, the import prices from the ROW are adjusted.

from the ROW ($p^{m,l}_{Rk,i}$) into Equation (33), the import prices from exogenous economies to Japan and the U.S., $p^{m,l}_{EJ,i}$ and $p^{m,l}_{EU,i}$, are affected. These then require the further adjustment in the estimates of $p^{d,l}_{J,i}$ and $p^{d,l}_{U,i}$ in Equation (23) of the main model, which impacts the third and fourth terms of the right-hand side of Equation (34) in the sub model. Through a few reiterations between the main model and the sub model, we obtain the final results of all types of PLIs between Japan and the U.S.

4 Sensitivity to Margin Rates

In this section, we evaluate the sensitivity of the PPPs for industry outputs to our choice of margin rates. Our baseline PPP estimates depend on the margin rates of wholesale and retail services estimated in Nomura and Miyagawa (2018a). They examined the accuracy of the estimates of the trade margin values in the 2011 benchmark IOT in Japan and found the total margin value was underestimated by about 40% due to estimation methods used in the 2011 Economic Census. If lower margin rates are used in the measurement of PPPs via the price model, they induce higher PPPs for industry outputs (Paths-2, -3, and -4 defined in Figure 2). Figure A2 presents the impact on the PPPs for outputs when the margin values were reduced by 40% (on the y-axis) from our baseline estimates (on the x-axis). This low-margin case reduces the price competitiveness measures by more than 50% in 15 industries and by more than 20% in 44 industries.[27] The PPPs based on the (official) low margin case imply significantly lower productivity levels in Japanese manufacturing than those based on the adjusted margins. These low productivity levels in manufacturing are implausible in comparison to earlier studies of Japan-U.S. productivity gaps.[28]

[27] For example, the PPP for industry output of 170.Motor vehicles is revised to 120.0 yen per dollar in low-margin case, compared to 97.5 in baseline estimates. The PPP for domestic output estimated in low-margin case seems to be unrealistically high as an evaluation of price competitiveness of the Japanese motor vehicle industry.

[28] Kuroda and Nomura (1999), and Jorgenson and Nomura (2007), as well as Jorgenson, Nomura and Samuels (2016).

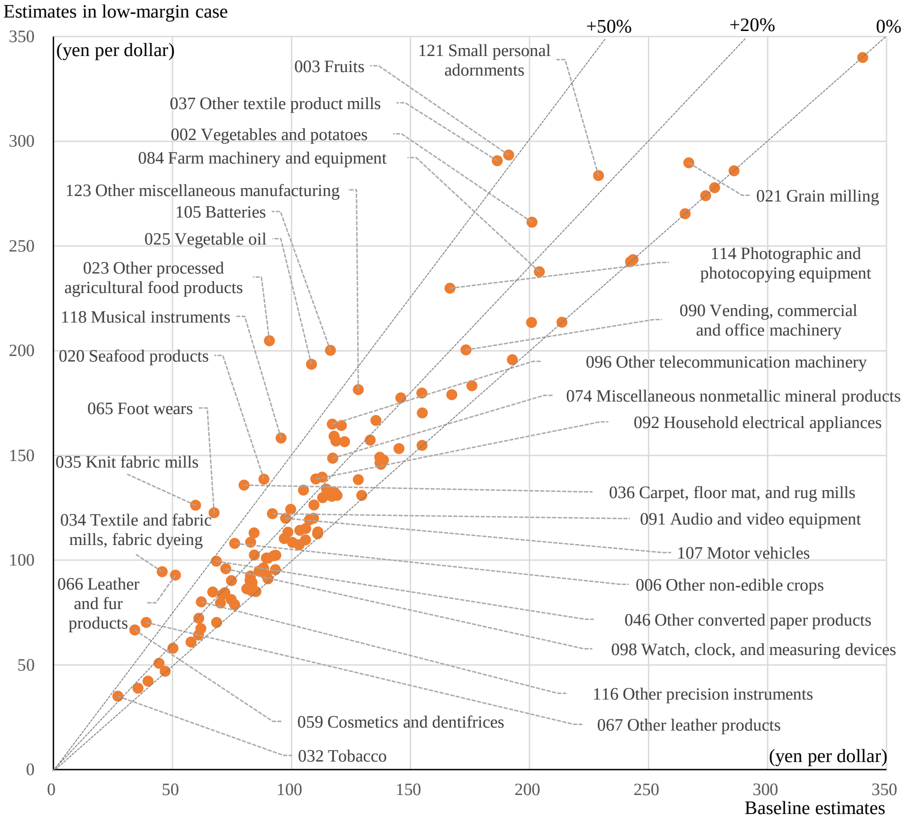

Figure A2: PPPs for Goods Based on the Low Margin Scenario versus the Baseline

At the aggregate level, the low-margin case leads to and increase the PPP for GDP to 111.8 yen per dollar, from 109.0 in the baseline scenario, expanding the gap with the expenditure-side PPP for GDP in the Eurostat-OECD (107.5 yen per dollar). However, the impact of the low-margin case at the aggregate level is small compared to the impacts at the industry level presented in Figure A2. This is because higher PPPs for GDP in the manufacturing industries are compensated by the revised lower PPPs for GDP of the wholesale and retail industries. The low-margin case has a significant impact on the PPP for wholesale service (95.3 yen per dollar from 133.5 in the baseline estimate) and the PPP for retail service (119.7 from 136.3). These estimates based on the lower margin rates seem to be inconsistent with previous studies, providing additional evidence that those based on the official Japan Census data appear implausible.