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1. Introduction

As manufacturing sectors of developed economies outsource more and more to developing economies, this may give rise to a serious measurement problem. If a manufacturing industry (or firm) procures a lot of parts and components from developing economies at exceptionally low prices and we do not correctly take account of these low prices, we will overestimate the productivity of this industry (or firm).

In this paper, we investigate two types of biases to manufacturing statistics from the growth in manufacturers' use of imported intermediates – commonly known as offshoring.

The first type of bias concerns measuring the use of imported products in the economy. Most countries, including the United States, do not track whether imports are destined for final demand or intermediate uses, but instead assume that industries use imports in proportion to their overall use of these products in the economy— this is the so-called import proportionality assumption. Measures using the import proportionality assumption will differ from measures based on actual input use if (a) industries' use of imports differs significantly from that assumed under the import proportionality assumption and (b) the price movements of imported and domestic intermediates within commodity classes differ significantly.[1] In this study we call these types of biases the bias caused by the import proportionality assumption.

The second type of bias concerns the price gap between domestically produced inputs and imported inputs. If manufacturers shift sourcing from a high-cost domestic supplier to a low-cost foreign supplier and statisticians do not take account of this price gap, statisticians' estimates of the inputs of these manufacturers will be downward biased and estimates of the TFP will be upward biased. This has been referred to as "offshoring bias" in the literature (Diewert and Nakamura 2011 and Houseman et al. 2011).

Japan presents an ideal case study to examine these two types of bias, that is, the bias caused by the import proportionality assumption and offshoring bias. The reason is that every five years, the Ministry of Internal Affairs and Communications publishes the *Input-Output Tables for Japan* (I-O tables), in which domestically produced intermediate inputs and imported intermediate inputs are treated separately. This class of I-O tables is called non-competitive import type I-O tables. The Japanese government estimates the input structure by conducting a special survey, implemented by the Ministry of Economy, Trade and Industry (METI), on the sources of each industry's

[1] A good discussion of these types of biases is provided by Howells et al. (2013).

procurements. Moreover, because of Japan's location, imports of intermediate inputs from China and other developing economies in East Asia have increased rapidly in recent decades. Against this background, using Japan's I-O tables and price indices for imported and domestic products, one of the major aims of this study is to estimate the bias caused by the import proportionality assumption by examining differences in estimates of import use in the I-O tables based on actual data and estimates based on the import proportionality assumption.

In order to estimate offshoring bias, we need—in addition to non-competitive import type I-O tables and price indices for imported and domestic products—data on the price gap between domestically produced inputs and imported inputs. In Japan, such data are available from the *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input* conducted by METI every year. This survey provides information on differentials in customer delivery prices among Japan, China, the United States, Germany, South Korea, Taiwan, and Hong Kong for about 180 commodities and 40 services. Using these data, we estimate the price gap between domestically produced inputs and imported inputs by country of origin.

The structure of the article is as follows. In the next section, we explain our methodology to estimate the two types of biases using data on Japan. In Section 3, we then explain our data. We also detail what data METI collects and how it collects these data. In Section 4, we report our results on bias caused by the import proportionality assumption. In Section 5, we report our results on offshoring bias. Section 6 concludes.

2. Approach to Measuring the Two Types of Biases

This section presents the approach we use to measure the two types of bias, that is, bias caused by the import proportionality assumption and offshoring bias.

We start by explaining our approach to measuring the bias caused by the import proportionality assumption.

In Japan, non-competitive import type input-output tables, in which domestically produced intermediate inputs and imported intermediate inputs are treated separately, are constructed every five years. Therefore, data on the nominal value of imported intermediate inputs from sector i to sector j, $X_{i,j}^{M}(t)$, and data on the nominal value of domestically produced intermediate inputs from sector i to sector j, $X_{i,j}^{H}(t)$, are available separately. Here, superscript M stands for imported intermediate inputs and H stands for domestically produced intermediate inputs. In the United States, it is usually competitive import type input-output tables that are estimated, and therefore only data on the total value of intermediate inputs from sector *i* to sector *j*, $X_{i,j}^{M}(t)+X_{i,j}^{H}(t)$, are available.

Let us theoretically examine biases caused by this shortcoming of U.S.-type input-output tables based on the assumption of competitive imports.

Assume that imported intermediate inputs from sector *i* to sector *j* and domestically produced intermediate inputs from sector *i* to sector *j* are different products and the cost share of each product reveals its marginal contribution to production in sector *j*.

In Japan, like in the United States, data on the absolute price levels of imported products and domestic products are not available. In both countries, only the price indices of imported products and domestic products are available. Let $P_i^M(t)/P_i^M(0)$ denote the price change of imported product *i* from year 0 to year *t* and $P_i^H(t)/P_i^H(0)$ denote the price change of domestically produced product *i* from year 0 to year *t*.[2]

For our estimation of the bias caused by the assumption of competitive imports, we prepared nominal and real non-competitive import type input-output tables for 1995, 2000, 2005 and 2008. As we will explain in detail in the next section, the main sources of our I-O tables are the *1995-2000-2005 Linked Input-Output Tables*, published by the Statistics Bureau of the Ministry of Internal Affairs and Communications (MIAC) and the *2008 Updated Input-Output Tables*, published by METI. Both of the statistics set 2005 as their benchmark year.

The key variables we would like to estimate are the real input indices for each sector. For the calculation of these quantity indices, we used 2005 as the base year. That is, we weighted input quantity changes by the nominal input values of 2005. Using Japan's non-competitive import type I-O tables, we derived the real input index for sector *j* for year *t* (*t*=1995, 2000, 2005, 2008), $x_j^J(t)$, as follows:

$$x_j^{J}(t)=\frac{\sum_i\left(X_{i,j}^{M}(T)\dfrac{\dfrac{X_{i,j}^{M}(t)}{P_i^{M}(t)}}{\dfrac{X_{i,j}^{M}(T)}{P_i^{M}(T)}}+X_{i,j}^{H}(T)\dfrac{\dfrac{X_{i,j}^{H}(t)}{P_i^{H}(t)}}{\dfrac{X_{i,j}^{H}(T)}{P_i^{H}(T)}}\right)}{\sum_i\left(X_{i,j}^{M}(T)+X_{i,j}^{H}(T)\right)}$$

[2] For ease of presentation, it is assumed here that each sector produces one product, so that subscript *i* is used to refer to both sectors and products.

$$= \frac{\sum_i \left(X_{i,j}{}^{M}(t) \frac{P_i^M(T)}{P_i^M(t)} + X_{i,j}{}^{H}(t) \frac{P_i^H(T)}{P_i^H(t)} \right)}{\sum_i \left(X_{i,j}{}^{M}(T) + X_{i,j}{}^{H}(T) \right)} \tag{1}$$

where the superscript J means that this index is based on non-competitive import type I-O tables like Japan's. T denotes the base year, 2005.[3]

In countries where non-competitive import type input-output tables are not regularly available, the ordinary approach is to assume that a sector's imports of each input, relative to its total demand, are the same as the economy-wide imports relative to total demand (as is assumed in the I-O tables for the United States).

That is, an industry's imports are calculated as follows. Let $m_i(t)$ denote the economy-wide imports of product i relative to total demand for product i:

$$m_i(t) = \frac{\sum_j X_{i,j}{}^{M}(t) + \sum_k F_{i,k}{}^{M}(t)}{\sum_j \left(X_{i,j}{}^{M}(t) + X_{i,j}{}^{H}(t) \right) + \sum_k \left(F_{i,k}{}^{M}(t) + F_{i,k}{}^{H}(t) \right)} \tag{2}$$

where $F_{i,k}{}^{M}(t)$ and $F_{i,k}{}^{H}(t)$ denote the value of imports of product i used to satisfy final demand k and the value of domestic output of product i used to satisfy final demand k.

In this shortcut approach, growth of real inputs from sector i to sector j is estimated by

$$m_i(t) \frac{\dfrac{X_{i,j}{}^{M}(t) + X_{i,j}{}^{H}(t)}{P_i^M(t)}}{\dfrac{X_{i,j}{}^{M}(T) + X_{i,j}{}^{H}(T)}{P_i^M(T)}} + \left(1 - m_i(t)\right) \frac{\dfrac{X_{i,j}{}^{M}(t) + X_{i,j}{}^{H}(t)}{P_i^H(t)}}{\dfrac{X_{i,j}{}^{M}(T) + X_{i,j}{}^{H}(T)}{P_i^H(T)}}$$

Moreover, the real input index for sector j for year t, $x_j^U(t)$, is defined by

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[3] Our quantity indices are based on the Laspeyres formula for years after the base year T and the Paasche formula for years before T.

$$x_j^U(t) = \frac{\sum_i \left(X_{i,j}{}^M(T) + X_{i,j}{}^H(T) \right) \left(m_i(t) \frac{\frac{X_{i,j}{}^M(t) + X_{i,j}{}^H(t)}{P_i^M(t)}}{\frac{X_{i,j}{}^M(T) + X_{i,j}{}^H(T)}{P_i^M(T)}} + (1 - m_i(t)) \frac{\frac{X_{i,j}{}^M(t) + X_{i,j}{}^H(t)}{P_i^H(t)}}{\frac{X_{i,j}{}^M(T) + X_{i,j}{}^H(T)}{P_i^H(T)}} \right)}{\sum_i \left(X_{i,j}{}^M(T) + X_{i,j}{}^H(T) \right)}$$

$$= \frac{\sum_i \left(X_{i,j}{}^M(t) + X_{i,j}{}^H(t) \right) \left(m_i(t) \frac{P_i^M(T)}{P_i^M(t)} + (1 - m_i(t)) \frac{P_i^H(T)}{P_i^H(t)} \right)}{\sum_i \left(X_{i,j}{}^M(T) + X_{i,j}{}^H(T) \right)} \tag{3}$$

where the superscript U means that this index is based on U.S.-type input-output tables based on the assumption of competitive imports.

Equation (3) shows that when the price of imports relative to that of domestic output declines ($P_i^M(T)/ P_i^H(T) > P_i^M(t)/ P_i^H(t)$) from T to t for most inputs i, we will underestimate the increase in intermediate inputs in sectors where imports of product i relative to the sector's total demand is higher than the economy-wide imports-domestic output ratio ($(X_{i,j}^M(t)/(X_{i,j}^M(t)+ X_{i,j}^H(t)) > m_i(t)$) for these inputs. As a result, we will overestimate the TFP growth of such sectors.

This type of bias caused by the assumption that an industry's imports of each input, relative to its total demand, are the same as the economy-wide imports relative to total demand, will be large if imports of each input, relative to the total demand for that input, are quite different across sectors and changes in the relative prices of imports and domestic products are large.

Biases caused by the import proportionality assumption have zero-sum characteristics. In some sectors, the imports-total demand ratio is higher than the economy-wide average, while in others, the ratio is lower. Therefore, these biases will tend to cancel each other out when we calculate macro-level TFP growth. However, if imports tend to be used more as intermediate inputs and domestic output tends to be used more for satisfying final demand, we will overestimate TFP growth of the macro economy when the prices of imports relative to those of domestic output decline.

Using Japan's I-O data from 1995 to 2008, we will analyze how the intermediate input index based on equation (1) moves differently from the intermediate input index based on equation (3).

Next, let us explain our methodology for measuring offshoring bias. The offshoring bias concerns the important caveat regarding our real input index $x_j^J(t)$, which is defined by equation (1) and is based on non-competitive import type I-O tables like Japan's. If quality-adjusted prices of imports i and that of domestic output i are different, then our intermediate input index defined by equation (1) is not appropriate for measuring true intermediate input growth. This issue was first pointed out by Diewert and Nakamura (2011) and empirically examined by Houseman et al. (2011).

If we express the (quality adjusted) absolute price level of imported products by $P_i^M(t)$ and the (quality adjusted) absolute price level of domestically produced products by $P_i^H(t)$, the appropriate input index of sector j for year t is defined by

$$x_j^O(t) = \frac{\sum_i \left\{ \left(X_{i,j}^M(T) + X_{i,j}^H(T) \right) \frac{\frac{X_{i,j}^M(t)}{P_i^M(t)} + \frac{X_{i,j}^H(t)}{P_i^H(t)}}{\frac{X_{i,j}^M(T)}{P_i^M(T)} + \frac{X_{i,j}^H(T)}{P_i^H(T)}} \right\}}{\sum_i \left(X_{i,j}^M(T) + X_{i,j}^H(T) \right)} \qquad (4)$$

where the superscript O means that this index is based on information on price gaps between domestically produced inputs and imported inputs and is free from offshoring bias.

Assume that imports are cheaper than domestically produced inputs and both prices, $P_i^M(t)$ and $P_i^H(t)$, are constant over time. Also assume that firms in sector j substitute imports for domestically produced inputs by the same amount, and imports and domestically produced inputs make the same marginal contribution to production. Then the true intermediate input index must remain constant. Input index $x_j^O(t)$, which is defined by equation (4), satisfies this condition. But both the input index $x_j^J(t)$, which is defined by equation (1), and the input index $x_j^U(t)$, which is defined by equation (3), decline. When we use $x_j^J(t)$ or $x_j^U(t)$, we will judge incorrectly that the intermediate input in sector i has decreased. Thus, we will overestimate the TFP growth of sector i.

Using METI's *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input* and Japan's I-O data, we will evaluate offshoring bias by comparing the intermediate input index $x_j^U(t)$ defined by equation (3) and the intermediate input index $x_j^O(t)$ defined by equation (4).

3. Data Used

In this section we explain the data we use for our analysis.

As nominal non-competitive import type input-output tables for 1995, 2000 and 2005, we use the *Input-Output Tables for Japan* for each of these years, published by the Statistics Bureau of the Ministry of Internal Affairs and Communications (MIAC). For these years, tables of imports reporting the nominal value of imports used as inputs in sector j, $X_{i,j}^M(t)$, and the nominal value of imports used to satisfy final demand k, $F_{i,k}^M(t)$, for each product i are available.

In order to construct these tables on imports, METI, which collaborates with MIAC, to compile the I-O tables conducts its survey on the use of major imports at the HS 9-digit level.[4] About 200 trading companies and producer associations are interviewed, with the latter, such as the association of electronics parts producers, the association of automobile parts producers, etc., making up the majority. This means that METI mainly asks the Japanese producers of each commodity about the destination industries of imports of these commodities, most of which are produced by their rivals abroad (of course, some Japanese producers are now multinationals and import from their own affiliates abroad). Table 1 provides an outline of the questionnaire form.

To extend our analysis to more recent years, we estimated non-competitive import type input-output tables for 2008 using the *2008 Updated Input-Output Tables* and the *2005 Input-Output Tables for Japan.* The updated I-O Tables do not contain tables on imports and we therefore estimated tables on imports by extrapolating data in import tables for 2005 using import data for 2008.

We obtain deflators for imports and domestic output separately for each sector i from the *1995-2000-2005 Linked Input-Output Tables* published by the Statistics Bureau, MIAC, and the *2008 Updated Input-Output Tables*. In these I-O tables, the major original sources of deflators for commodities are the domestic corporate goods price index (DCGPI) and the import price index (IPI) taken from the *Corporate Goods Price Index* published by the Bank of Japan.

Using these various sources, we prepared nominal and real non-competitive import type input-output tables for 1995, 2000, 2005 and 2008. The endogenous sector table for each year has 514 rows and 401 columns. In our analysis, we set 2005 as our benchmark year for our calculation of the quantity and the price index before and after 2005.

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[4] In 2013, this survey became one of Japan's General Statistics and is now called the *Survey on Input-Output Structure (Survey on Sale Destination of Import Goods).*

Table 1. Outline of the Questionnaire Form for *the Survey on Demand for Imported Commodities*

Survey on Demand for Imported Commodities for the Year 2010

Note: Please enter the percentage share of each final consumer of each commodity.

Form A	
HS Code (9 digit)	
(Japan's HS code 9 digit classification contains 2,784 commodities)	
HS Commodity Name	
Interviewed at	
	Sectoral distribution of imported commodity (nominal value of imported commodity demanded by that sector/nominal value of total imports)
Intermediate input by 32 sectors	%
Agriculture, forestry and fishery	4
Mining	3
….	
….	
Electrical machinery	25
….	
….	
Household services	
Business services	30
….	
Final demand	
Household consumption	2
Government consumption	10
Private investment	4
Government investment	3
…..	
Total	100

Form B	
Please provide the final destination of the commodity by 4 digit and 6 digit industry classification for the two sectors that make up the highest shares in Form A.	
4 digit table	
Electrical machinery	
Electronics parts	
Household electric appliances	
Sub-total	25
Business services	
…..	
Sub-total	30
6 digit table	
Electrical machinery	
…..	
Electronics parts	
Semiconductors	
Condensers	
Sub-total	25
Business services	
…..	
Sub-total	30

Moreover, for data on price gaps necessary for our analysis we used METI's *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input*. This survey has been conducted every year from 1993 and reports differences of customer delivery price of about 150 intermediate goods and 30 services between Japan on the one hand and the United States, China, Germany, and the Newly Industrializing Economies (NIES, consisting of South Korea, Hong Kong, Taiwan, and Singapore) on the other. The survey specifies each commodity and service in great detail. In the case of commodities, the survey in principle follows the commodity specification of the *Corporate Goods Price Index* published by the Bank of Japan.

As we will report detail in Section 5, unit prices in the developing economies included in the survey, i.e., China and the NIEs, for many products tend to be much lower than unit prices in the developed economies, i.e., Japan, the United States, and Germany. This implies that it would be inappropriate to assume, as is done in equation (4), that the unit prices of Japanese imports are identical regardless of the country of origin. We therefore distinguish between imports from developed and from developing economies.

The number of goods and services covered by the survey differs across countries and across years. Data are relatively abundant for U.S.–Japan and China–Japan price differences from 2000 and we therefore use data for the two pairs for 2000 and 2008.[5]

We grouped Japan's trade partners into two groups, developed economies consisting of the United States and countries that were members of the European Union in 2000 and developing economies consisting of China and the rest of the world. We assume that price differentials between Japan and the developed economies are the same as the U.S.–Japan price differentials and price differentials between Japan and the developing economies are the same as the China–Japan price differentials.

A potential problem is that customer delivery prices in the United States and China reported in METI's survey may include prices of imported goods, but what we would like to know is the price gaps between domestically produced goods and imported goods from China and the United States in Japan. However, because we have no way of knowing whether the customer delivery prices in the United States and China reported in the METI survey include imported goods, we assume that the price gaps reported in

[5] In the case of the 2000 survey, the survey investigates absolute price levels in each country's currency during the period September–November 2000 and coverts these prices into prices in Japanese yen using average market exchange rates during the survey period. The exchange rates were 108.00 yen/U.S. dollar and 13.05 yen/Chinese yuan. In the case of the 2008 survey, the survey period was July–September 2008 and the exchange rates were 107.60 yen/U.S. dollar and 15.74 yen/Chinese yuan.

the survey are good indicators of the price gaps between domestically produced goods and imported goods in Japan.

Another, related issue is that in Japan's I-O tables, the value of domestic products is given on a producer price basis, while the value of imported products is on a CIF (cost, insurance and freight) basis. On the other hand, METI's survey reports price gaps between customer delivery prices in Japan and customer delivery prices in other countries. Because of trade costs, it is likely that the ratio of the price of imported products on a CIF basis over price of domestic products will tend to be higher than the ratio of customer delivery prices in other countries over customer delivery prices in Japan. In order to adjust for this factor, we assume for each commodity that the ratio of the price of imported products on a CIF basis over the price of domestic products is 10 percent higher than the ratio of customer delivery prices in other countries over customer delivery prices in Japan.

In our analysis of offshoring bias, we use 2000 as the base year and set the producer price of domestic product *i* in year 2000, $P_i^H(2000)$, equal to one for all *i*. We derive the CIF price of product *i* in year 2000 imported from developed economies, $P_i^D(2000)$, and the CIF price of product *i* in year 2000 imported from developing economies, $P_i^L(2000)$, for each *i* using the following equations:

$$P_i^D(2000) = 1.1 \frac{\Pi_i^D(2000)}{\Pi_i^H(2000)} P_i^H(2000) \qquad (5)$$

$$P_i^L(2000) = 1.1 \frac{\Pi_i^L(2000)}{\Pi_i^H(2000)} P_i^H(2000) \qquad (6)$$

where $\Pi_i^H(2000)$, $\Pi_i^D(2000)$, and $\Pi_i^L(2000)$ respectively denote the customer delivery price of product *i* in year 2000 in Japan, the United States, and China, which we take from METI's *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input*.

As for the CIF prices of product *i* in year 2008 imported from developed and developing economies, both in terms of the customer delivery price of product *i* in year 2000 in Japan, one way to estimate this is to use the customer delivery price in year 2008 in Japan, the United States, and China respectively and sectoral deflators in the I-O tables. That is, we can derive the CIF price of product *i* in year 2008 imported from developed economies, $P_i^D(2008)$, the CIF price of product *i* in year 2008 imported from developing economies, $P_i^L(2008)$, for each i, and the producer price of domestic product i in year 2008, $P_i^H(2008)$, for each i using the following equations:

$$P_i^D(2008) = 1.1 \frac{\Pi_i^D(2008)}{\Pi_i^H(2008)} \frac{P_i^H(2008)}{P_i^H(2000)} P_i^H(2000) \tag{7}$$

$$P_i^L(2008) = 1.1 \frac{\Pi_i^L(2008)}{\Pi_i^H(2008)} \frac{P_i^H(2008)}{P_i^H(2000)} P_i^H(2000) \tag{8}$$

$$P_i^H(2008) = \frac{P_i^H(2008)}{P_i^H(2000)} P_i^H(2000) \tag{9}$$

where $\Pi_i^H(2008)$, $\Pi_i^D(2008)$, and $\Pi_i^L(2008)$ denote the customer delivery price of product i in year 2008 in Japan, the United States, and China, respectively. We obtain $P_i^H(2008)/\ P_i^H(2000)$ from the sectoral deflators in the *1995-2000-2005 Linked Input-Output Tables* and the *2008 Updated Input-Output Tables*.

We should note that there is another important source of import price change in addition to the combined data of METI's *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input* and the sectoral deflators in the *1995-2000-2005 Linked Input-Output Tables* and the *2008 Updated Input-Output Tables*, namely, the import deflators in the I-O tables. The import deflators in the I-O tables are mainly based on the *Corporate Goods Price Index* published by the Bank of Japan, which covers much more commodities and countries of origin than METI's survey. The import deflators in the I-O tables therefore likely are more reliable than our estimates using equations, (7), (8) and (9), but the I-O tables do not contain data on import prices by country of origin or on absolute price gaps Taking these advantages and disadvantages of the import deflator in the I-O tables into account, we use these deflators as a kind of a control total, as we shall explain below.

The CIF price of product i in year 2008 imported from developed economies, $P_i^D(2008)$, and the CIF price of product i in year 2008 imported from developing economies, $P_i^L(2008)$, are expected to satisfy the following equation:

$$\frac{P_i^M(2008)}{P_i^M(2000)} = m_i^D(2008)\frac{P_i^D(2008)}{P_i^D(2000)} + \left(1 - m_i^D(2008)\right)\frac{P_i^L(2008)}{P_i^L(2000)} \tag{10}$$

where $P_i^M(t)$ denotes Japan's import price of product i from the rest of the world in year t. $m_i^D(t)$ denotes the percentage of Japan's imports of product i from developed economies in Japan's total imports in 2008. We obtain these data from the *Trade Statistics of Japan* published by the Ministry of Finance.

Because of the differences in data sources and other factors, such as the fact that we use price difference data only for the U.S.–Japan and China–Japan pairs, while the import deflators in the I-O tables cover all of Japan's imports from the world, $P_i^D(2008)$ and $P_i^L(2008)$ derived from equations (8) and (9) do not necessarily satisfy equation (10). To make $P_i^D(2008)$ and $P_i^L(2008)$ consistent with equation (10), we add an adjustment term γ on the right-hand side of equations (8) and (9) and redefine $P_i^D(2008)$ and $P_i^L(2008)$ as follows:

$$P_i^D(2008) = 1.1\gamma \frac{\Pi_i^D(2008)}{\Pi_i^H(2008)} \frac{P_i^H(2008)}{P_i^H(2000)} P_i^H(2000) \tag{11}$$

$$P_i^L(2008) = 1.1\gamma \frac{\Pi_i^L(2008)}{\Pi_i^H(2008)} \frac{P_i^H(2008)}{P_i^H(2000)} P_i^H(2000) \tag{12}$$

where γ is defined by

$$\gamma = \frac{\dfrac{P_i^M(2008)}{P_i^M(2000)}}{m_i^D(2008)\dfrac{\dfrac{\Pi_i^D(2008)}{\Pi_i^H(2008)}\dfrac{P_i^H(2008)}{P_i^H(2000)}}{\dfrac{\Pi_i^D(2000)}{\Pi_i^H(2000)}} + \left(1 - m_i^D(2008)\right)\dfrac{\dfrac{\Pi_i^L(2008)}{\Pi_i^H(2008)}\dfrac{P_i^H(2008)}{P_i^H(2000)}}{\dfrac{\Pi_i^L(2000)}{\Pi_i^H(2000)}}}$$

It can be easily confirmed that $P_i^D(2008)$ and $P_i^L(2008)$ defined by equations (11) and (12) satisfy equation (10).

Our input index for sector j for year t, which is based on information on price gaps between domestically produced inputs and imported inputs and is free from offshoring bias, is defined by the following equation:

$$x_j^{\ O}(t)=\frac{\sum_i\left\{\left(X_{i,j}^{\ \ M}(T)+X_{i,j}^{\ \ H}(T)\right)\frac{\frac{m_i^D(t)X_{i,j}^{\ \ M}(t)}{P_i^D(t)}+\frac{\left(1-m_i^D(t)\right)X_{i,j}^{\ \ M}(t)}{P_i^L(t)}+\frac{X_{i,j}^{\ \ H}(t)}{P_i^H(t)}}{\frac{m_i^D(T)X_{i,j}^{\ \ M}(T)}{P_i^D(T)}+\frac{\left(1-m_i^D(T)\right)X_{i,j}^{\ \ M}(T)}{P_i^L(T)}+\frac{X_{i,j}^{\ \ H}(T)}{P_i^H(T)}}\right\}}{\sum_i\left(X_{i,j}^{\ \ M}(T)+X_{i,j}^{\ \ H}(T)\right)} \tag{13}$$

for t=2000, 2008 and T=2000. This is a modified version of equation (4).

Two additional caveats with regard to our data should be pointed out. Firstly, METI's survey on price differentials does not cover food processing and agricultural, fishery, and forestry output, while the coverage of service output is very limited. Therefore, we calculated price gaps only for the output of the mining and manufacturing sectors other than processed food, and assumed that there are no price differentials in the case of agricultural, forestry, and fishery products, food processing, and services. Moreover, due to this limitation in the data, we excluded the food processing sector from our analysis of the offshoring bias.

Secondly, even in the case of non-food commodities, the number of commodities reported in the survey (about 180) is not sufficient for the estimation of price gaps for our disaggregated 3-digit level I-O tables, in which we have 285 rows, consisting of the mining sector and manufacturing sectors other than processed food. Therefore, for industries in the I-O tables which we could not match at the 3-digit level, we assumed that the price gap was the same as at the more aggregated 2-industry level. Moreover, when the METI survey provides price gap data on multiple commodities that correspond to one of the 285 industry rows, we calculated the industry average price gap for that industry employing the weights used in the METI survey. The original source of the weights is the *Corporate Goods Price Index* published by the Bank of Japan.

4. Estimation of Bias Caused by the Import Proportionality Assumption

Using our data, we analyze how the prices of imported inputs relative to domestically produced inputs changed as well as how much the share of imported inputs in total inputs differs across sectors and how this share changed between 1995 and 2005. In addition, we estimate the bias caused by the import proportionality assumption by comparing the intermediate input index based on information from the tables on imports and the index based on the assumption that an industry's imports of each input, relative to its total demand, are the same as the economy-wide imports relative to total demand (as is assumed in the I-O tables for the United States).

As we explained in Section 2, the bias caused by the assumption that an industry's imports of each input, relative to its total demand, are the same as the economy-wide imports relative to total demand, will be large if changes in the relative prices of imports and domestic products are large and if imports of each input, relative to the total demand for that input, are quite different across sectors.

Figure 1 shows how the ratio of the average price index of imported inputs over the average price index of domestically produced inputs has changed over time. As can be seen, the ratio declined by 40 percent in the period 1995–2008. This decline was not caused by yen appreciation, since, as Figure 1 also shows, the value of the yen as measured by the real effective exchange rate, fell by more than 50 percent during the same period. Rather, a likely reason for the decline in relative import prices is the increase in Japan's imports of low-priced products from Asian countries and decline of output price in countries of origin.[6]

[6] As we have already explained, we obtain deflators for imports and domestic output separately for each sector *i* from the 1995-2000-2005 Linked Input-Output Tables published by the Statistics Bureau, MIAC, and the 2008 Updated Input-Output Tables. In these I-O tables, the major original sources of deflators for commodities are the domestic corporate goods price index (DCGPI) and the import price index (IPI) taken from the Corporate Goods Price Index published by the Bank of Japan. When Bank of Japan compiles IPI, it specifies each commodity in great detail and tracks price changes of same commodity from same country of origin. Therefore, shift of imports from high-price countries to low-price countries will not affect IPI and deflators of the I-O tables. But in the case of some of imported raw materials and manufactured products, for which IPI data is not available, the I-O tables use unit price of imports as deflators. In the case of these products, shift of imports from high-price countries to low-price countries will reduce deflators of the I-O tables. Therefore the decline in relative import prices in Figure 1 reflects not only the decline of output price in countries of origin but also the increase in Japan's imports of low-priced products from Asian countries. We should also note that in the case of these products, for which unit price of trade statistics are used as import deflators, equation (10) does not hold in a rigorous way. When unit price of imports declines because of shift from high-cost exporters to low-cost exporters, there will be a risk that equations (11) and (12) overestimate price decline in exporting countries.

Figure 1. Average Price of Imported Inputs over Average Price of Domestically Produced Inputs (1995=1) and Japan's Real Effective Exchange Rate (Yen/Foreign Currency): 1995-2008

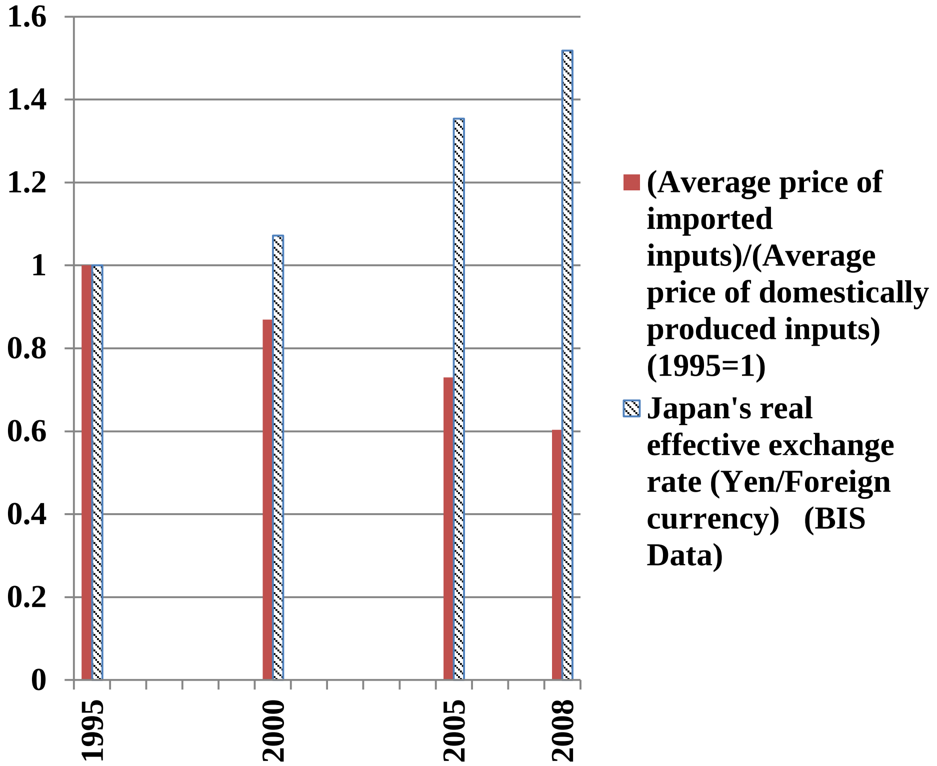


Figure 2 shows the regional composition of Japan's imports of manufactured products for 2000, 2005 and 2008. Similarly, Figure 3 shows the regional composition of Japan's imports of machinery imports for 2000, 2005 and 2008. The figures show that the share of imports from China and other Asian countries in Japan's total manufacturing and machinery imports increased rapidly in the 2000s.

Figure 2. Regional Composition of Japan's Imports of Manufactured Products: 2000, 2005 and 2008

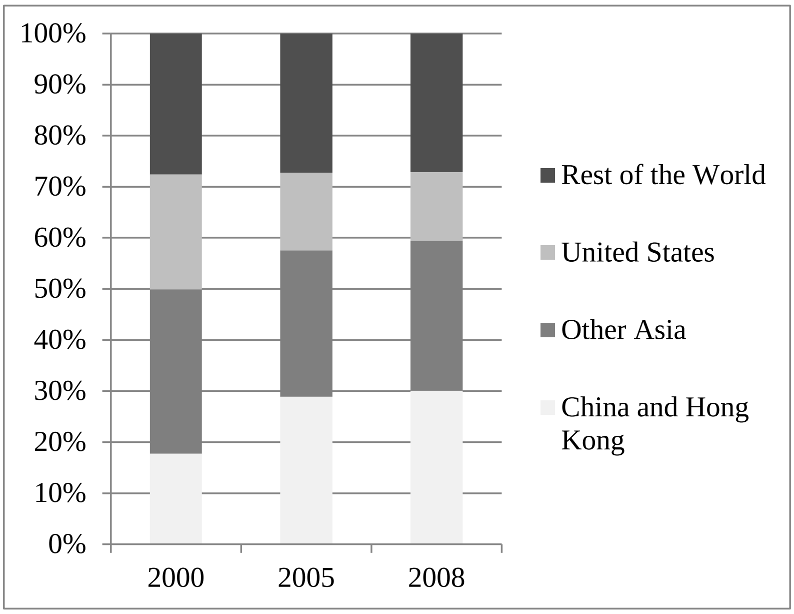
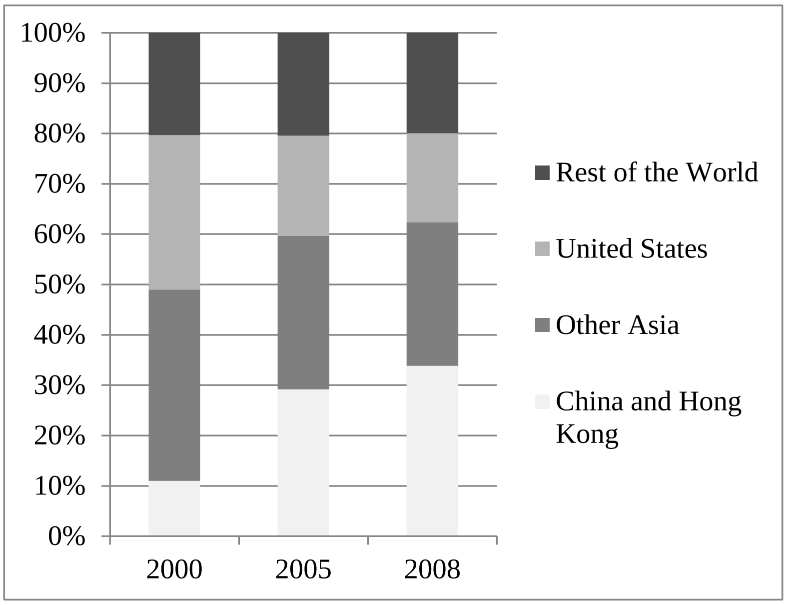


Figure 3. Regional Composition of Japan's Imports of Machinery: 2000, 2005 and 2008



Next, Table 2 provides a list of commodities for which the ratio of the price of imports over the price of domestic products declined by more than 25 percent from 1995 to 2008. Cells showing machinery products are highlighted. The table confirms that the import price-domestic price ratio of many commodities, including important parts and components, sharply declined during the period. For instance, in the case of integrated circuits and semiconductor devices, the relative price declined by 33 percent and 28 percent, respectively.

The next issue we examine is how much the share of imported inputs in total inputs differs across sectors and how this share has changed over time. We do so by focusing on integrated circuits and semiconductor devices. The results are shown in Figures 4 and 5.

Starting with integrated circuits, the nominal value of total intermediate inputs increased from 3.0 trillion yen in 1995 to 3.6 trillion yen in 2005.[7] While this increase in the nominal value is not particularly large, intermediate input in real terms in fact increased threefold. The share of the total nominal input of imports in total nominal input increased from 34 percent to 58 percent. The increase in the share of the total nominal input of imports was even more pronounced in the case of semiconductor devices, where it jumped from 18 percent to 61 percent.

However, as can be seen in Figures 4 and 5, the share of imports in total demand differs considerably across sectors. In both cases, the import ratio tends to be high in electrical machinery sectors, but relatively low in other sectors such as automobiles and precision machinery. This means that we will underestimate the growth of these electronics parts inputs in electrical machinery sectors and overestimate it in other machinery sectors if we assume that an industry's imports of each input, relative to its total demand, are the same as the economy-wide imports relative to total demand.

We calculate the extent of underestimation, $\ln(x_j^U(2008)/\ x_j^I(2008))$- $\ln(x_j^U(1995)/\ x_j^I(1995))$ for all the 202 manufacturing sectors other than processing food and all the 6 mining sectors, using our data. Table 3 shows the 50 sectors in which the underestimation of intermediate input growth is largest among these 208 mining and manufacturing sectors.[8] By multiplying this value with two values, that is, with minus one and with the average of the nominal intermediate input-nominal gross output ratio of a particular sector for 1995 and 2008, we also calculate the extent of the overestimation of TFP growth for the period 1995–2008.

In the top 15 sectors in which the underestimation of intermediate input growth caused by the import proportionality assumption is largest (namely, animal oils and fats;

[7] The reason that we focus on the period up to 2005 and not up to 2008 here is that we had to estimate the table on imports for 2008 and therefore think that the table on imports for 2005 is more reliable.

[8] The reason that we are focusing only on 208 and not 285 industries is as follows. As explained in Section 3, the endogenous table we use is not symmetric. The table for each year has 514 rows and 401 columns. Out of the 514 rows, 285 rows are for mining and manufacturing sectors other than food processing. We prepared our special data on prices, imported intermediate inputs by country of origin, etc. for these 285 row sectors. Out of the 401 columns, 208 rows are for mining and the manufacturing sectors other than food processing. We calculated biases of intermediate inputs and TFP growth for these 208 column sectors.

ordnance; aircrafts; liquid crystal elements; methane derivatives; organic fertilizers, n.e.c.; video recording and playback equipment; thermo-setting resins; salt; bicycles; turbines; glass fiber and glass fiber products, n.e.c.; and integrated circuits) the negative bias of intermediate input growth caused by the import proportionality assumption is more than 2.6 percent and the positive bias of TFP growth is more than 1.7 percent. These sectors include important “high tech” machinery sectors, such as aircrafts and integrated circuits.

Next, Table 4 shows the 50 sectors in which the overestimation of intermediate input growth is largest among all the manufacturing sectors. These include cellular phones, radio and television sets, coal products, other non-ferrous metal products, repair of aircrafts, and other photographic and optical instruments, where the positive bias of intermediate input growth is 3.3 percent and the negative bias of TFP growth is more than 1.9 percent.

Table 2. Commodities for which the Import Price-Domestic Price Ratio Declined by More than 25% from 1995 to 2008

Sector	Import price /Domestic price of 2008 (1995=1)	Sector	Import price /Domestic price of 2008 (1995=1)	Sector	Import price /Domestic price of 2008 (1995=1)
Other petroleum refinery products	0.174	Printing, plate making and book binding	0.539	Condiments and seasonings	0.673
Natural gas	0.215	Rolling stock	0.547	Integrated circuits	0.674
Video recording and playback equipment	0.230	Polyethylene (low density)	0.551	Engines	0.675
Miscellaneous cereals	0.239	Bread	0.552	Other livestock	0.686
Coal mining	0.245	Other non-metallic ores	0.554	Processed meat products	0.686
Forged steel	0.279	Tea and roasted coffee	0.555	Other hot rolled steel (ordinary steel)	0.687
Iron ores	0.291	Soft drinks	0.556	Other electrical devices and parts	0.689
Other coal products	0.316	Heavy oil B and C	0.557	Cooking oil	0.693
Electric audio equipment	0.324	Steel pipes and tubes (ordinary steel)	0.558	Methane derivatives	0.694
Crude steel (electric furnaces)	0.331	Synthetic rubber	0.560	Other aliphatic intermediates	0.697
Gasoline	0.351	Internal combustion engines for motor vehicles and parts	0.560	Other office machines	0.699
Personal computers	0.356	Cast materials (iron)	0.565	Rice	0.699
Ethylene glycol	0.361	Gas and oil appliances and heating and cooking apparatus	0.567	Dextrose, syrup and isomerized sugar	0.699
Crops for inedible agricultural products, n.e.c.	0.367	Hen eggs	0.572	Polyethylene (high density)	0.700
Preserved agricultural foodstuffs (other than bottled or	0.367	Other liquors	0.577	Crops for feed and forage	0.702
Industrial plastic products	0.367	Gravel and quarrying	0.581	Other non-ferrous metal products	0.703
Optical fiber cables	0.376	Cast iron pipes and tubes	0.598	Electrical equipment for internal combustion engines	0.705
Vending machines	0.379	Noodles	0.600	Cement	0.706
Steel ships	0.385	Other resins	0.600	Hot rolled steel (special steel)	0.710
Photographic sensitive materials	0.385	Total of intermediate sectors	0.604	High function resins	0.712
Coke	0.400	Tobacco	0.609	Synthetic phenol	0.712
Magnetic tapes and discs	0.407	Metal containers, fabricated plate and sheet metal	0.609	Miscellaneous leather products	0.712
Acetic acid	0.429	Electron tubes	0.617	Steel bar (ordinary steel)	0.715
Glass processing materials	0.433	Other fruits	0.620	Timber	0.715
Agricultural chemicals	0.434	Steep plate (ordinary steel)	0.624	Bottled or canned meat products	0.717
Other cyclic intermediates	0.452	Other pulses	0.625	Bicycles	0.719
Dairy products	0.459	Pure toluene	0.628	Semiconductor devices	0.720
Oil seeds	0.465	Pig iron	0.632	Nuclear fuels	0.722
Non-ferrous metal castings and forgings	0.466	Ships (except steel ships)	0.635	Batteries	0.726
Printing ink	0.468	Other glass products, n.e.c.	0.635	Starch	0.726
Electronic computing equipment (except personal	0.468	Clay refractories	0.637	Woolen fabrics, hemp fabrics and other fabrics	0.728
Chemical fertilizer	0.481	Medicaments	0.638	Sawmill, wood working, veneer and plywood machinery	0.728
Plywood	0.484	Other meat (bone meat)	0.644	Citrus fruits	0.730
Radio and television sets	0.485	By-products of slaughtering and meat processing	0.644	Other foods	0.732
Pure benzene	0.487	Catalyzer	0.648	Bottled or canned seafood	0.737
Fowls and broilers	0.493	Other inorganic pigments	0.648	Surface active agents	0.742
Other materials for ceramics	0.502	Pulp equipment and paper machinery	0.651	Rolled and drawn aluminum	0.743
Household air-conditioners	0.508	Metal products for construction	0.651	Watches and clocks	0.743
Carpets and floor mats	0.515	Milled rice	0.658	Other grain milling	0.745
Toys and games	0.518	Titanium oxide	0.660	LPG (liquefied petroleum gas)	0.745
Wheat flour	0.525	Synthetic alcohol	0.664	Other machinery for service industry	0.746
Limestone	0.527	Household electric appliances (except air-conditioners)	0.668	Passenger motor cars	0.746
Other industrial inorganic chemicals	0.529	Soda ash	0.672	Oil and fat industrial chemicals	0.747
Beer	0.530	Apples	0.673	Acrylonitrile	0.748
Rice straw	0.533	Other photographic and optical instruments	0.673	Metal products for architecture	0.754

Figure 4. Share of Imported Inputs in Total Inputs: Integrated Circuits, 1995-2005

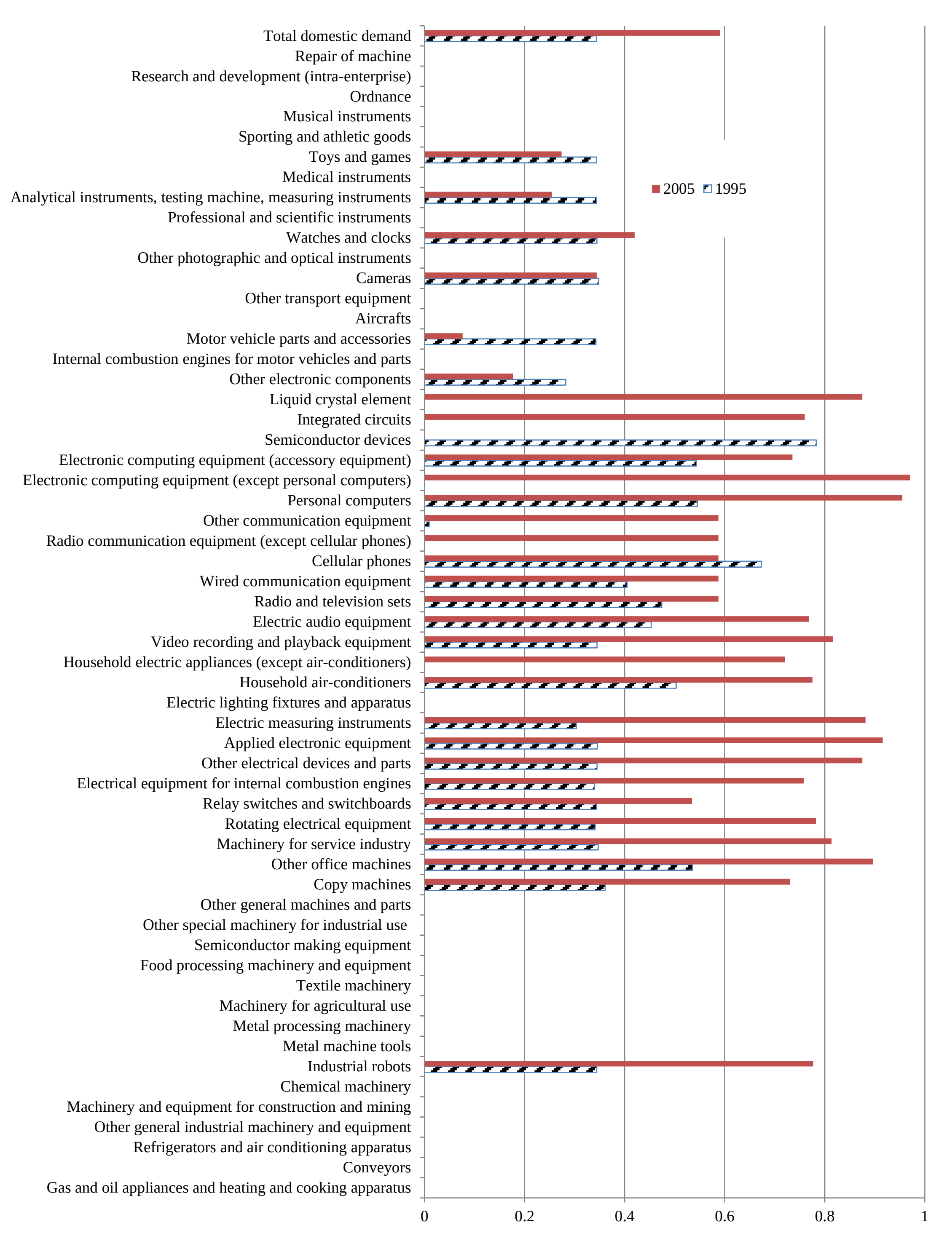


Figure 5. Share of Imported Inputs in Total Inputs: Semiconductor Devices, 1995-2005

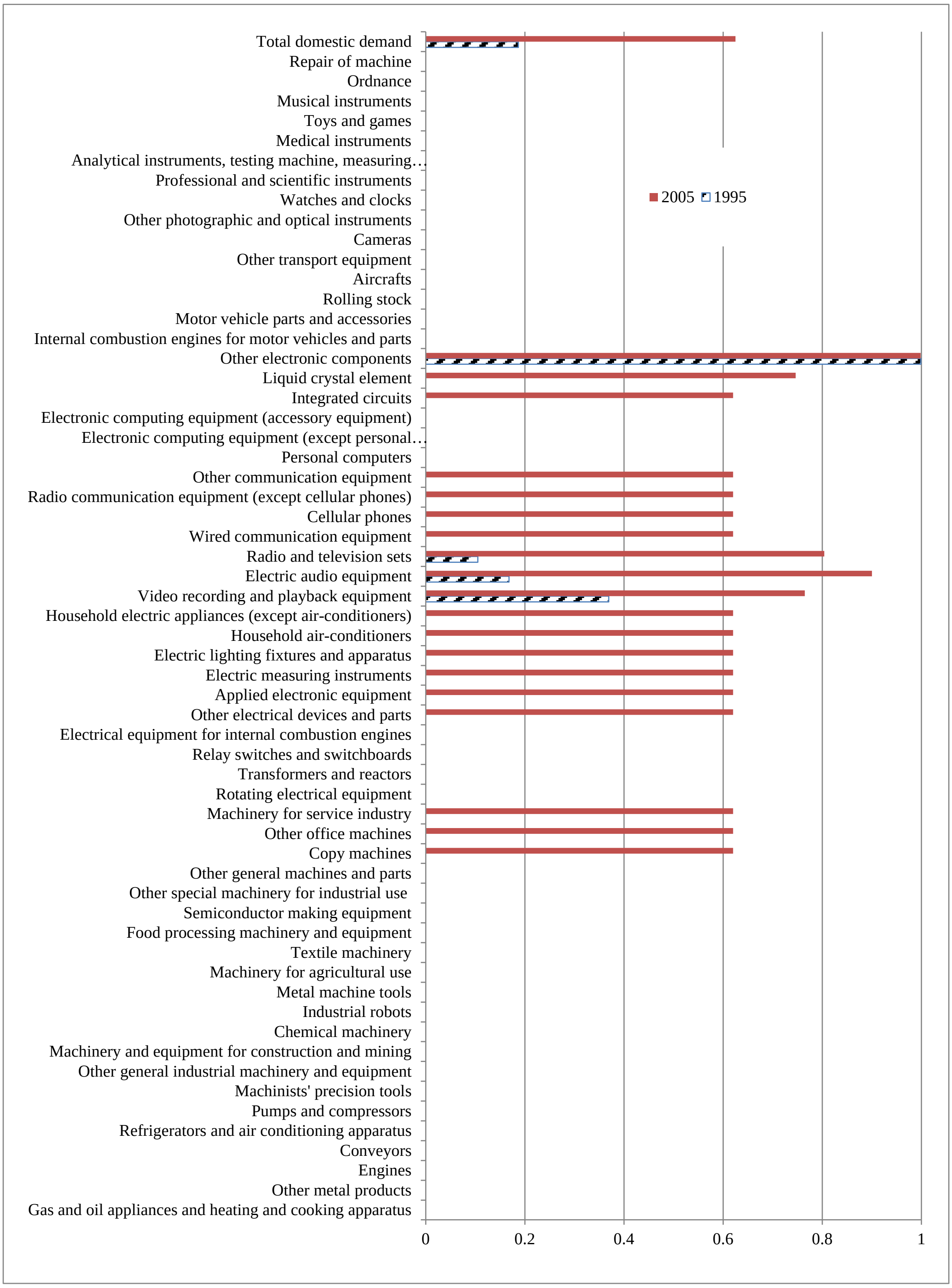


Table 3. Underestimation of Intermediate Input Growth as a Result of the Import Proportionality Assumption: Top 50 Sectors, 1995-2008

Sector	Underestimation of intermediate input growth, $\ln(x^U/x^J)$ (1995-2008)	Intermediate input/Gross output (Average value of 1995 and 2008)	Overestimation of TFP growth on a gross output basis (1995-2008)
	A	B	A*B
Animal oils and fats	-14.04%	0.715	10.04%
Ordnance	-12.62%	0.619	7.81%
Aircrafts	-9.85%	0.538	5.29%
Liquid crystal elements	-8.13%	0.727	5.91%
Methane derivatives	-6.90%	0.742	5.12%
Organic fertilizers, n.e.c.	-4.49%	0.657	2.95%
Video recording and playback equipment	-4.25%	0.722	3.07%
Thermo-setting resins	-4.13%	0.733	3.03%
Salt	-4.13%	0.546	2.25%
Bicycles	-3.73%	0.720	2.68%
Turbines	-3.38%	0.643	2.17%
Glass fiber and glass fiber products, n.e.c.	-3.20%	0.604	1.93%
Integrated circuits	-2.62%	0.650	1.70%
Processed meat products	-2.62%	0.710	1.86%
"Tatami" (straw matting) and straw products	-2.47%	0.703	1.74%
Wooden chips	-2.39%	0.733	1.75%
Other resins	-2.34%	0.749	1.75%
Other glass products	-1.94%	0.537	1.04%
Non-ferrous metal castings and forgings	-1.85%	0.703	1.30%
Dextrose, syrup and isomerized sugar	-1.72%	0.820	1.41%
High function resins	-1.49%	0.778	1.16%
Electronic computing equipment (except personal computers)	-1.45%	0.716	1.04%
Optical fiber cables	-1.28%	0.740	0.95%
Applied electronic equipment	-1.22%	0.716	0.88%
Watches and clocks	-1.21%	0.630	0.76%
Machinery for service industry	-1.10%	0.725	0.79%
Plywood	-1.07%	0.690	0.74%
Rolling stock	-1.03%	0.745	0.77%
Electric measuring instruments	-1.03%	0.652	0.67%
Cameras	-1.02%	0.689	0.70%
Cement	-1.00%	0.697	0.69%
Food processing machinery and equipment	-0.97%	0.587	0.57%
Sporting and athletic goods	-0.96%	0.676	0.65%
Rotating electrical equipment	-0.88%	0.649	0.57%
Cast and forged steel	-0.78%	0.517	0.41%
Internal combustion engines for vessels	-0.77%	0.691	0.53%
Other electrical devices and parts	-0.75%	0.642	0.48%
Repair of rolling stock	-0.73%	0.636	0.46%
Relay switches and switchboards	-0.71%	0.634	0.45%
Other foods	-0.70%	0.595	0.41%
Bottled or canned meat products	-0.69%	0.726	0.50%
Iron and steel shearing and slitting	-0.69%	0.788	0.54%
School lunchs (public)	-0.69%	0.567	0.39%
Musical instruments	-0.67%	0.609	0.41%
Copy machines	-0.67%	0.800	0.53%
Personal computers	-0.66%	0.804	0.53%
Motor vehicle bodies	-0.65%	0.757	0.49%
Professional and scientific instruments	-0.62%	0.569	0.35%
Transformers and reactors	-0.61%	0.597	0.36%
Passenger motor cars	-0.58%	0.858	0.50%

Table 4. Overestimation of Intermediate Input Growth as a Result of the Import Proportionality Assumption: Top 50 Sectors, 1995-2008

Sector	Overestimation of intermediate input growth, $\ln(x^U/x^J)$ (1995-2008)	Intermediate input/Gross output (Average value of 1995 and 2008)	Underestimation of TFP growth on a gross output basis (1995-2008)
	A	B	A*B
Cellular phones	5.49%	0.782	-4.30%
Radio and television sets	5.47%	0.780	-4.27%
Coal products	4.04%	0.825	-3.33%
Other non-ferrous metal products	3.70%	0.715	-2.64%
Repair of aircrafts	3.49%	0.656	-2.29%
Other photographic and optical instruments	3.25%	0.592	-1.92%
Confectionery	3.04%	0.580	-1.76%
Electric audio equipment	2.96%	0.742	-2.20%
Leather and fur skins	2.87%	0.692	-1.98%
Bottled or canned vegetables and fruits	2.69%	0.770	-2.07%
Chemical fertilizer	2.54%	0.685	-1.74%
Other electrical devices and parts	2.41%	0.630	-1.52%
Retort foods	2.40%	0.704	-1.69%
Dishes, sushi and lunch boxes	2.16%	0.697	-1.50%
Synthetic dyes	2.12%	0.649	-1.38%
Other metal products	1.88%	0.463	-0.87%
Batteries	1.80%	0.733	-1.32%
Other electronic components	1.78%	0.690	-1.23%
Medicaments	1.67%	0.608	-1.01%
Dairy farm products	1.49%	0.779	-1.16%
Steel pipes and tubes	1.42%	0.759	-1.08%
Other industrial organic chemicals	1.26%	0.672	-0.84%
Soap, synthetic detergents and surface active agents	1.21%	0.715	-0.86%
Synthetic fibers	1.21%	0.633	-0.77%
Preserved agricultural foodstuffs (other than bottled or canned)	1.21%	0.631	-0.76%
Nuclear fuels	1.21%	0.541	-0.65%
Inorganic pigment	1.18%	0.687	-0.81%
Other liquors	1.16%	0.483	-0.56%
Oil and fat industrial chemicals	1.15%	0.650	-0.74%
Bread	1.11%	0.561	-0.62%
Petrochemical basic products	1.09%	0.920	-1.01%
Compressed gas and liquefied gas	1.07%	0.685	-0.74%
Other industrial inorganic chemicals	1.02%	0.629	-0.64%
Clay refractories	0.96%	0.603	-0.58%
Carpets and floor mats	0.90%	0.754	-0.68%
School lunches (private)	0.90%	0.561	-0.50%
Electric bulbs	0.86%	0.605	-0.52%
Feeds	0.84%	0.873	-0.74%
Prepared frozen foods	0.84%	0.659	-0.56%
Engines	0.82%	0.727	-0.60%
Sheet glass and safety glass	0.81%	0.562	-0.46%
Bolts, nuts, rivets and springs	0.81%	0.544	-0.44%
Petroleum refinery products (inc. greases)	0.77%	0.634	-0.49%
Noodles	0.76%	0.630	-0.48%
Jewelry and adornments	0.71%	0.680	-0.48%
Machinery and equipment for construction and mining	0.70%	0.673	-0.47%
Bedding	0.58%	0.668	-0.38%
Starch	0.58%	0.775	-0.45%
Tires and inner tubes	0.57%	0.688	-0.39%
Carbon and graphite products	0.50%	0.589	-0.30%

5. Estimation of Offshoring Bias

Using our data, we estimate offshoring bias by comparing the real input index based on information on the price gaps between domestically produced and imported intermediate inputs. That is, we estimate equation (13) in Section 3, which is a modified version of equation (4) in Section 2, and the real input index based on the assumption that an industry's imports of each input, relative to the total demand for that input, are the same as the economy-wide imports relative to total demand (as is assumed in the I-O tables for the United States), i.e., equation (3) in Section 2. For the estimation, we use year 2000 as our base year and calculate how the two types of intermediate input index for each sector changed from 2000 to 2008. In addition, we analyze how much of a price gap there exists between domestically produced intermediate inputs, inputs imported from developed economies, and inputs imported from developing economies, as well as how these price gaps changed from 2000 to 2008.

As Diewert and Nakamura (2011) and Houseman et al. (2011) explained, offshoring bias tends to be greater when there are large price gaps between domestically produced intermediate inputs and imported inputs and firms substitute imports for domestically produced inputs to a substantial extent.

Figures 6 and 7 show our results of estimating the price gaps between domestically produced intermediate inputs, inputs imported from developed economies, and inputs imported from developing economies for 2000 and 2008, respectively. For the calculation, we used equations (5), (6), (9), (11), and (12). In the two figures, the price levels of domestically produced products are set to one for both 2000 and 2008. Moreover, for the figures, we aggregated the estimated price gaps for the 285 sectors into 53 sectors. As explained in Section 3, our estimation of the price gaps between developed economies and Japan is based on U.S.–Japan price differentials and our estimation of the price gaps between developing economies and Japan is based on China–Japan price differentials

The two figures show that in the case of price gaps between domestically produced inputs and inputs imported from developed economies, domestically produced inputs are not always more expensive than imported inputs. On the contrary, in many sectors, including most of the machinery sectors, the price level of domestically produced inputs was lower than the price level of inputs imported from developed economies both in 2000 and in 2008.

Figure 6. Price Gaps between Domestically Produced Inputs and Imported Inputs from Developed and Developing Economies: 2000

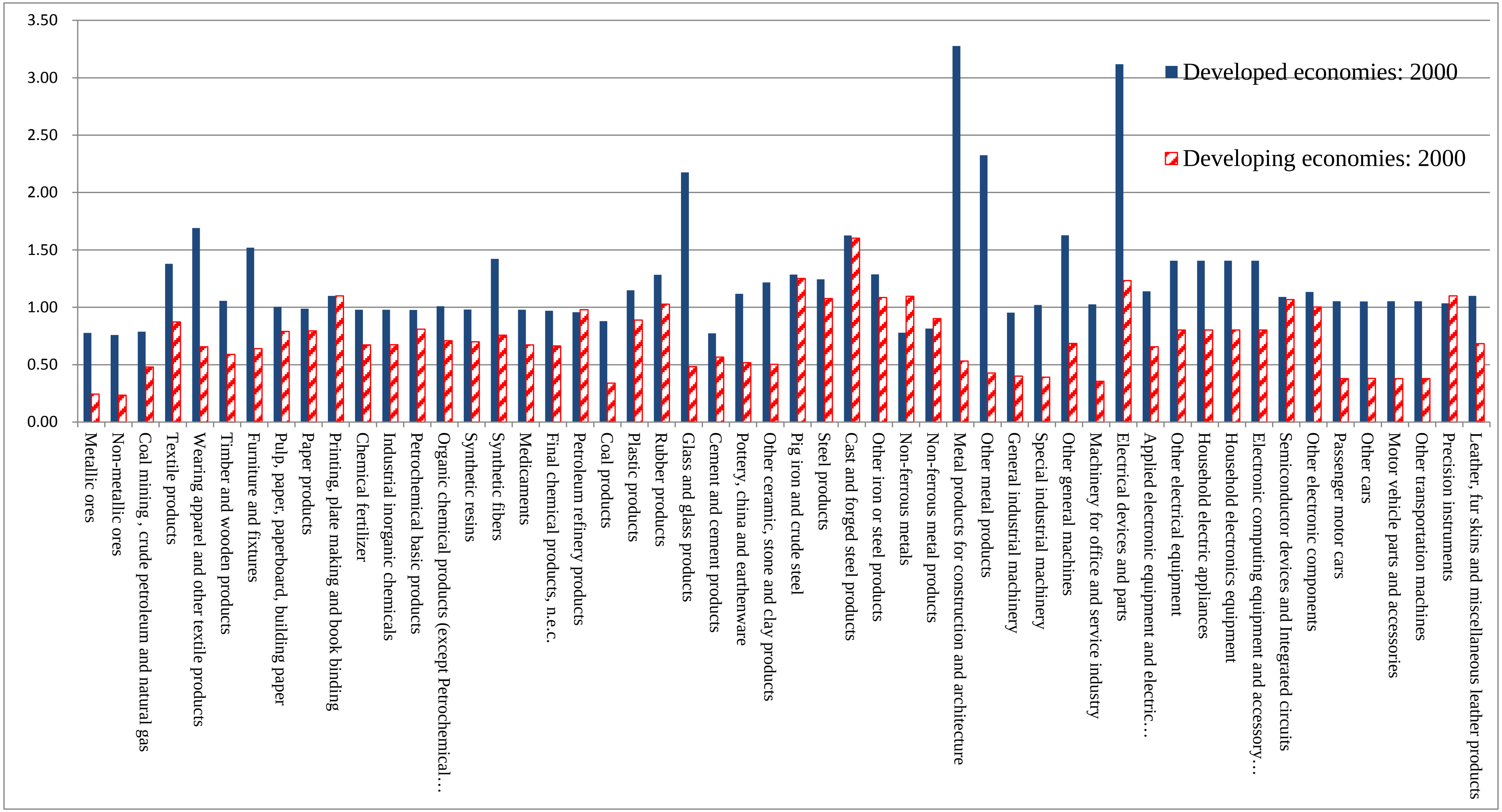
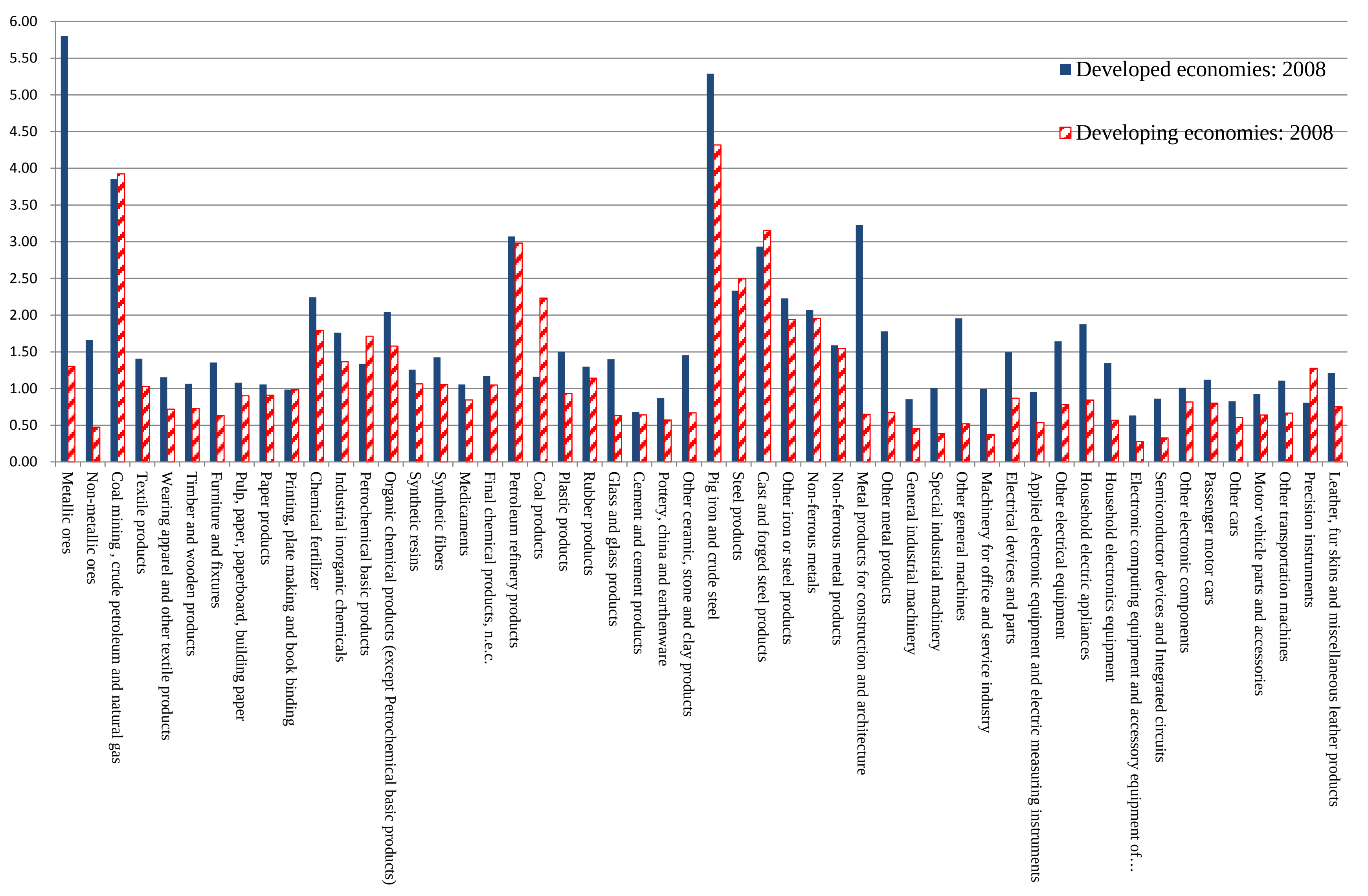


Figure 7. Price Gaps between Domestically Produced Inputs and Imported Inputs from Developed and Developing Economies: 2008



In the case of price gaps between domestically produced inputs and inputs imported from developing economies, imported inputs are cheaper than domestically produced inputs in most of the sectors. Moreover, both in 2000 and 2008, the price gap is considerable not only in the case of most of light industry products such as wearing apparel and other textile products, timber and wooden products, leather, and fur skins and miscellaneous leather products, but also in the case of most machinery products.

Comparing the price gaps between domestically produced inputs and inputs imported from developing economies in 2000 and 2008, the gaps do not seem to have widened in most sectors, although there are some exceptions such as electronic computing equipment and accessory equipment of electronic computing equipment, and semiconductor devices and integrated circuits. In fact, price gaps narrowed slightly in some sectors, probably because of rapid increases in wages in, as well as appreciation of the exchange rates of, many of developing economies, including China.

These results suggest that during this period there was no large offshoring bias caused by a sharp decline in the prices of inputs imported from developing economies, except in the case of the electrical machinery industry. However, even though prices of imported inputs generally may not have fallen, it is still possible that there was substantial offshoring bias as a result of the rapid increase of imported inputs at prevailing price gaps. As seen in Figures 2 and 3, the share of imports of manufactured products from China, Hong Kong, and other Asian economies in Japan's total imports increased considerably between 2000 and 2008. Moreover, Figure 8 shows that Japan's imports of machinery increased not only in the case of final goods but also in the case of many types of parts and components.

To examine whether the rapid rise in imported inputs from developing countries gave rise to offshoring bias, we calculate the extent of underestimation of intermediate input growth, $\ln(x_j^U(2008)/\ x_j^O(2008))\text{-}\ \ln(x_j^U(2000)/\ x_j^O(2000))$, using our data. By multiplying this value with minus one and with the average value of the nominal intermediate input-nominal gross output ratio of a particular sector for 2000 and 2008, we also calculate the extent of the overestimation of TFP growth for the period 2000-2008.

Table 5 shows the 50 sectors in which the underestimation of intermediate input growth is largest among all the 208 mining and manufacturing sectors other than food processing. Probably reflecting the fact that Japan's imports of cheap electrical parts and components from developing economies increased substantially, the 50 sectors include many electrical machinery sectors such as liquid crystal elements, personal computers, electronic computing equipment (except personal computers), and electric measuring instruments. Among the 50 sectors, 25 sectors produce machinery. Cells showing machinery sectors are highlighted.

In many sectors, especially in machinery sectors, offshoring bias is of a substantial size that cannot be ignored. For example, Table 5 shows that the TFP growth rate in liquid crystal elements and personal computers are overestimated by 5.92% and 5.34% respectively (the annual rate in log value are 0.74% and 0.67%, respectively).

We should note that the biases shown in Table 5 contain both biases caused by the import proportionality assumption and biases caused by gaps in the absolute price levels between imported products and domestically produced products. It is probably for this reason that many electrical machinery sectors such as liquid crystal elements, personal computers, electronic computing equipment (except personal computers), and electric measuring instruments, appear both in Table 3 and Table 5.

Comparing Tables 3 and 5, we also find that the biases in Table 5 tend to be much larger than those in Table 3, although the period covered by Table 5 is 5 years shorter than the period covered by Table 3. The minimum value of the bias in TFP growth in Table 5 is 1.72% (for cast iron pipes and tubes), which is much larger than the minimum value of the bias in TFP growth in Table 3, 0.50% (for passenger motor cars). It seems that biases caused by gaps in the absolute price levels between imported products and domestically produced products are a more serious problem than biases caused by the import proportionality assumptions.

In the case of the overestimation of intermediate input growth, such overestimation occurred in only 29 out of the 208 mining and manufacturing sectors other than food processing. That is, in 179 sectors intermediate inputs were underestimated. Table 6 shows the 29 sectors in which intermediate input growth was overestimated (i.e., $\ln(x_j^U(2008)/\ x_j^O(2008))$- $\ln(x_j^U(2000)/\ x_j^O(2000)$ took positive values). Among the 29 sectors, only 5 sectors produce machinery. We also find that in many sectors the magnitude (absolute value) of the underestimation of TFP growth caused by offshoring bias is smaller than the magnitude (absolute value) of the overestimation of TFP growth caused by offshoring bias, which is reported in Table 5.

As pointed out in Section 2, biases caused by the import proportionality assumption have zero-sum characteristics. In some sectors, the imports-total demand ratio is higher than the economy-wide average, while in others, the ratio is lower. Therefore, these biases will tend to cancel each other out when we calculate macro-level TFP growth.

However, offshoring biases do not have such zero-sum characteristics. If a majority of sectors shift their sourcing from high-cost domestic suppliers to low-cost foreign suppliers, the TFP growth of all these sectors will be overestimated, and the TFP growth of the economy as a whole will be also overestimated. Table 5 and table 6 show that TFP growth was overestimated in 179 out of the 208 mining and manufacturing sectors during the period 2000–2008. It therefore seems likely that the TFP growth of Japan's economy as a whole during this period may also have been overestimated.

Figure 8. Japan's Imports of Machinery from Developing Economies: 2000 and 2008

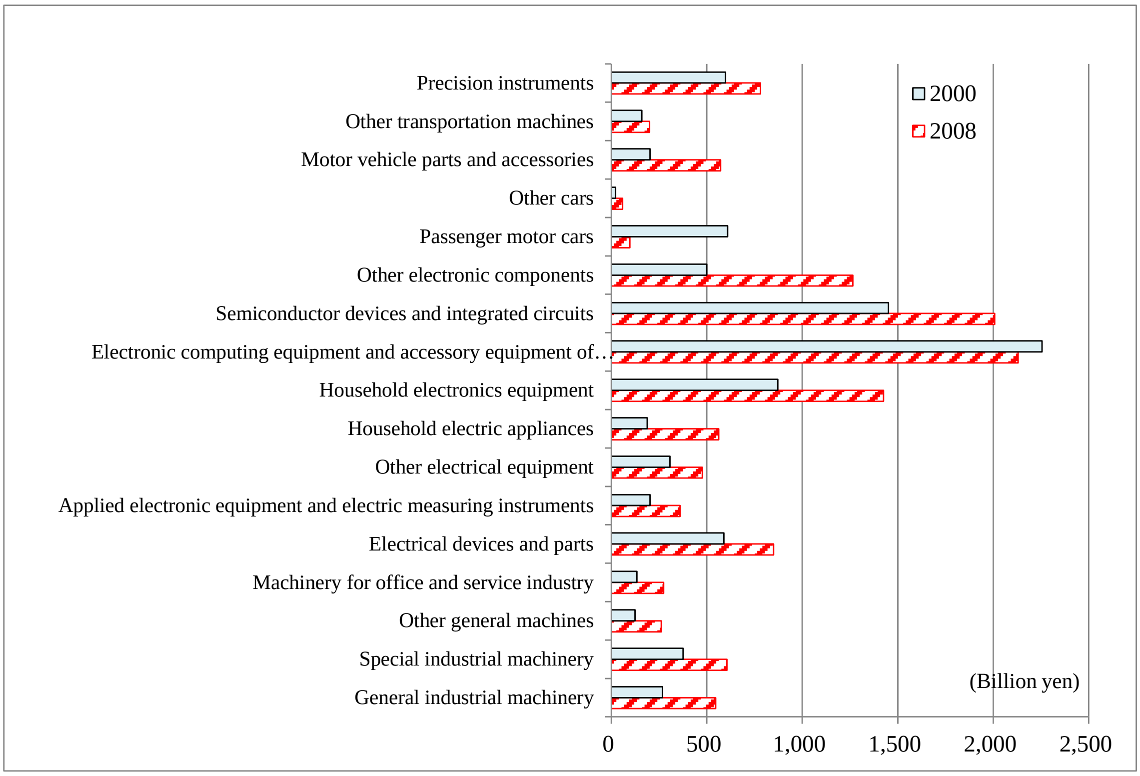


Table 5. Underestimation of Intermediate Input Growth by the Offshoring Bias: Top 50 Sectors, 2000-2008

Sector	Underestimation of intermediate input growth, $\ln(x^U/x^O)$ (2000-2008)	Intermediate input/Gross output (Average value of 2000 and 2008)	Overestimation of TFP growth on a gross output basis (2000-2008)
	A	B	A*B
"Tatami" (straw matting) and straw products	-15.47%	0.738	11.41%
Nuclear fuels	-13.14%	0.551	7.24%
Toys and games	-9.92%	0.700	6.95%
Pumps and compressors	-8.90%	0.644	5.73%
Rayon and acetate	-8.84%	0.678	6.00%
Other non-metallic ores	-8.55%	0.578	4.94%
Liquid crystal element	-8.21%	0.721	5.92%
Metallic ores	-7.78%	0.465	3.62%
Salt	-7.10%	0.535	3.80%
Repair of aircrafts	-6.87%	0.674	4.63%
Pulp	-6.87%	0.858	5.90%
Food processing machinery and equipment	-6.85%	0.582	3.98%
Sheet glass and safety glass	-6.72%	0.582	3.91%
Personal computers	-6.56%	0.814	5.34%
Paperboard	-6.36%	0.722	4.59%
Other non-ferrous metal products	-6.29%	0.706	4.44%
Electronic computing equipment (except personal computers)	-6.25%	0.748	4.68%
Electric measuring instruments	-6.24%	0.660	4.12%
Other office machines	-6.13%	0.737	4.52%
Coal mining , crude petroleum and natural gas	-5.84%	0.428	2.50%
Boilers	-5.66%	0.575	3.25%
Textile machinery	-5.46%	0.594	3.24%
Machinists' precision tools	-5.44%	0.540	2.93%
Bearings	-5.40%	0.596	3.22%
Other structural clay products	-4.87%	0.537	2.62%
Chemical machinery	-4.77%	0.574	2.74%
Other wooden products	-4.75%	0.547	2.60%
Video recording and playback equipment	-4.66%	0.753	3.51%
Applied electronic equipment	-4.53%	0.738	3.35%
Leather and fur skins	-4.44%	0.683	3.04%
Cement products	-4.43%	0.503	2.23%
Other paper containers	-4.38%	0.604	2.65%
Methane derivatives	-4.19%	0.746	3.12%
Conveyors	-4.12%	0.698	2.87%
Other general industrial machinery and equipment	-4.08%	0.625	2.55%
Cast and forged steel	-3.95%	0.536	2.12%
Two-wheel motor vehicles	-3.92%	0.821	3.22%
Engines	-3.90%	0.727	2.84%
Cement	-3.84%	0.707	2.71%
Household air-conditioners	-3.80%	0.737	2.80%
Pottery, china and earthenware	-3.65%	0.556	2.03%
Electronic computing equipment (accessory equipment)	-3.62%	0.770	2.79%
Motor vehicle bodies	-3.58%	0.764	2.74%
Ships (except steel ships)	-3.53%	0.610	2.16%
Cameras	-3.51%	0.698	2.45%
Plumber's supplies, powder metallurgy products and tools	-3.47%	0.548	1.90%
Abrasive	-3.38%	0.522	1.76%
Machinery for service industry	-3.33%	0.733	2.44%
Cast iron pipes and tubes	-3.33%	0.519	1.72%
Wooden furniture and fixtures	-3.26%	0.617	2.01%

Table 6. Overestimation of Intermediate Input Growth as a Result of the Offshoring Bias: 29 Sectors in which the Bias was Overestimated, 2000-2008

Sector	Overestimation of intermediate input growth, $\ln(x^U/x^O)$ (2000-2008)	Intermediate input/Gross output (Average value of 2000 and 2008)	Underestimation of TFP growth on a gross output basis (2000-2008)
	A	B	A*B
Synthetic dyes	8.42%	0.692	-5.82%
Cyclic intermediates	6.46%	0.843	-5.44%
Plasticizers	3.93%	0.707	-2.78%
Other resins	2.77%	0.765	-2.12%
Synthetic fibers	2.44%	0.653	-1.59%
Oil and fat industrial chemicals	1.94%	0.649	-1.26%
Rolled and drawn aluminum	1.62%	0.769	-1.25%
Tires and inner tubes	1.41%	0.695	-0.98%
Chemical fertilizer	1.33%	0.700	-0.93%
Turbines	1.29%	0.636	-0.82%
Pig iron	1.14%	0.811	-0.93%
Timber	1.14%	0.645	-0.73%
Soap, synthetic detergents and surface active agents	1.07%	0.710	-0.76%
Thermo-setting resins	1.02%	0.757	-0.77%
Other industrial inorganic chemicals	0.98%	0.645	-0.63%
Plywood	0.87%	0.664	-0.58%
Cotton and staple fiber fabrics (inc. fabrics of synthetic spun fil	0.84%	0.714	-0.60%
Other photographic and optical instruments	0.70%	0.591	-0.41%
Electric lighting fixtures and apparatus	0.68%	0.674	-0.46%
Other electronic components	0.55%	0.713	-0.39%
High function resins	0.52%	0.806	-0.42%
Fiber yarns	0.48%	0.701	-0.34%
Wooden fixtures	0.46%	0.639	-0.29%
Metal products for architecture	0.38%	0.623	-0.24%
Gelatin and adhesives	0.29%	0.651	-0.19%
Medicaments	0.27%	0.618	-0.17%
Optical fiber cables	0.26%	0.779	-0.20%
Petroleum refinery products (inc. greases)	0.06%	0.692	-0.04%
Electron tubes	0.02%	0.710	-0.01%

6. Conclusion

Using import tables and other data from Japan's input-output tables for 1995, 2000, 2005, and 2008, we estimated how much and in what direction the intermediate input index and TFP growth will be biased if we assume that an industry's imports of each input, relative to the total demand for the input, are the same as the economy-wide imports relative to total demand. We also examined offshoring bias, which concerns the price gap between domestically produced inputs and imported inputs. For this analysis, we used METI's *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input* in addition to I-O tables.

Our main findings are as follows.

1. Our theoretical analysis showed that the bias caused by the import proportionality assumption will be large if imports of each input, relative to the total demand for it, are quite different across sectors and changes in the relative prices of imports and domestic products are large.

2. Japan experienced a 40 percent decline in the ratio of the average price of imported inputs over the average price of domestically produced inputs in the period 1995–2008. This decline was not caused by yen appreciation, since the value of the yen as measured by the real effective exchange rate in fact fell by more than 50 percent during the same period. Rather, a likely reason for the decline in relative import prices is the increase in Japan's imports of low-priced products from Asian countries.

3. The import price-domestic price ratio of many commodities, including important parts and components, declined sharply during the period 1995–2008.

4. We examined how the share of imported inputs in total inputs differs across sectors, focusing on the case of integrated circuits and semiconductor devices. We found that for both types of input, the import ratio tends to be high in the electrical machinery sectors. Moreover, the ratio is relatively low in other sectors such as automobiles and precision machinery.

5. We found that the bias caused by the import proportionality assumption is quite large in some sectors. For example, in animal oils and fats, ordnance, aircrafts, liquid crystal elements, methane derivatives, organic fertilizers, n.e.c., video recording and playback equipment, thermo-setting resins, salt, bicycles, turbines, glass fiber and glass fiber products, n.e.c., and integrated circuits, the negative bias of intermediate input growth caused by the import proportionality assumption is more than 2.5 percent and the positive offshoring bias of TFP growth is more than 1.7 percent.

6. On the other hand, in cellular phones, radio and television sets, coal products, other non-ferrous metal products, repair of aircrafts, and other photographic and optical instruments, the positive offshoring bias of intermediate input growth is more than 3.3 percent and the negative offshoring bias of TFP growth is more than 1.9 percent.

7. Next, we estimated offshoring biases caused by the price gap between domestically produced inputs and imported inputs and substitution of intermediate

inputs from expensive domestic products to cheap foreign products. In the case of price gaps between domestically produced inputs and inputs imported from developing economies, imported inputs are cheaper than domestically produced inputs in most sectors. Moreover, both in 2000 and 2008, the price gap was relatively large not only in the case of most light industry products, such as wearing apparel and other textile products, timber and wooden products, leather, fur skins and miscellaneous leather products, but also in the case of most machinery products.

8. In the 2000s, Japan's imports of machinery from developing economies increased not only in the case of final goods but also in the case of many types of parts and components. As a result of the rapid increase of imported inputs at prevailing price gaps, in many sectors, especially in machinery sectors, a substantial offshoring bias that cannot be ignored arose. For example, the TFP growth rates for the liquid crystal elements and personal computers sectors are overestimated by 5.92% and 5.34% respectively (the annual rate in log value was 0.74% and 0.67%, respectively).

9. Reflecting the fact that Japan's imports of cheap electrical parts and components from developing economies increased substantially, the 50 sectors in which the underestimation of intermediate input growth is largest include many electrical machinery sectors such as liquid crystal elements, personal computers, electronic computing equipment (except personal computers), and electric measuring instruments.

10. Biases caused by the import proportionality assumption have zero-sum characteristics. In some sectors, the imports-total demand ratio is higher than the economy-wide average, while in others, the ratio is lower. Therefore, these biases will tend to cancel each other out when we calculate macro-level TFP growth. In contrast, offshoring biases do not have such zero-sum characteristics. If most sectors shifted their sourcing from high-cost domestic suppliers to low-cost foreign suppliers, the TFP growth of these sectors will be overestimated. In this case, the TFP growth of the economy as a whole will also be overestimated. We found that during the period 2000–2008 TFP growth was overestimated as a result of offshoring bias in 179 out of the 208 mining and manufacturing sectors we examined. Consequently, Japan's TFP growth at macro-level during this period may be also overestimated.

One of the key findings is that there are relatively large biases due to offshoring in a substantial number of manufacturing sectors, including important machinery sectors.

This means that the issue of biases from offshoring should be taken into account in future productivity analyses at the sectoral and firm levels. Moreover, since offshoring activities are likely to continue increasing, data collection by statistical offices to grapple with such offshoring biases will be of growing importance.

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