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The Impact on Japanese Industry of Alternative Carbon Mitigation Policies

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RESOURCES FOR THE FUTURE

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Abstract

To address the climate change issue, developed nations have considered introducing carbon pricing mechanisms in the form of a carbon tax or an emissions trading scheme (ETS). Despite the small number of programs actually in operation, these mechanisms remain under active discussion in a number of countries, including Japan. Using an input–output model of the Japanese economy, this paper analyzes the effects of carbon pricing on Japan's industrial sector. We also examine the impact of a rebate program of the type proposed for energy intensive trade exposed (EITE) industries in U.S. legislation, the Waxman–Markey bill (H.R. 2454), and in the European Union's ETS. We find that a carbon pricing scheme would impose a disproportionate burden on a limited number of sectors—namely, pig iron, crude steel (converters), cement, and other EITE industries. We also find that the determinant of the increase in total cost differs among industries, depending on the relative inputs of directly combusted fossil fuel, electricity, or steam, as well as intermediate goods.

Out of 401 industries, 23 would be eligible for rebates if a Waxman–Markey type of program were adopted in Japan. Specifically, the 85 percent rebate provided to eligible industries under H.R. 2454 would significantly reduce the cost of direct and indirect fossil fuel usage. The E.U. criteria identify 120 industries eligible for rebates. However, the E.U. program only covers direct emissions while the U.S. program includes indirect emissions as well. Overall, despite the differences in coverage, we find that the Waxman–Markey and E.U. rebate programs have roughly similar impacts in reducing the average burdens on EITE industries.

Key Words: carbon price, competitiveness, input-output analysis, output-based allocations, carbon leakage

JEL Classification Numbers: F14, D21, D57, D58, H23

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Makoto Sugino, Toshi H. Arimura, and Richard Morgenstern*

1. Introduction

To address the climate change issue, developed nations have considered introducing carbon pricing mechanisms in the form of a carbon tax or an emissions trading scheme (ETS). Despite the small number of programs actually in operation, these mechanisms remain under active discussion in a number of countries, including Japan. Using an input–output model of the Japanese economy, this paper analyzes the effects of carbon pricing on Japan's industrial sector. We also examine the impact of a rebate program of the type proposed for energy intensive trade exposed (EITE) industries in U.S. legislation, the Waxman–Markey bill (H.R. 2454), and in the European Union's ETS.

Although a carbon pricing mechanism would induce producers and consumers to reduce their carbon emissions, it would do so at a significant cost to EITE industries, as some production might relocate to nations with either limited or no regulation of CO_2 emissions. This potential movement of energy-intensive production raises concerns about the manufacturing sector in developed countries, known as the competitiveness issue.

The impacts of carbon prices on industries, however, can depend on the design of the carbon pricing policy. To offset cost increases due to carbon pricing in the E.U. ETS, EITE industries are given free allowances based on an industry-wide benchmark. In the U.S., the American Clean Energy and Security Act of 2009 (H.R. 2454, also known as the Waxman–Markey climate bill), which passed the House of Representatives in 2009, has somewhat similar provisions.

The Japanese government has tried to implement a carbon tax ranging from \2,600 to \3,600/t-C (US$26 to $36). In addition, the Japanese government has considered a domestic ETS. Despite extensive discussion of a national-level ETS, such a scheme is not likely to be

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introduced in Japan in the next few years. However, the government has agreed to introduce a carbon tax of \1,060/per ton of carbon (t-C).

Although several studies have previously examined the impact of carbon prices on the overall economy and on the household sector, limited research has focused on the potential impacts of such a scheme on Japanese industry. The methods used to assess the impacts of carbon prices in previous analyses can be broadly divided into two categories: computational general equilibrium (CGE) analysis and input–output (I–O) analysis. CGE models allows for changes in the production function. Thus, changes in input prices result in changes in demand for substitute inputs. Therefore, CGE models can be considered models for estimating impacts in the long run, where the input mix of energy and other factors can be adjusted. In contrast, simple I–O models, which assume fixed production functions, are best used for estimating impacts in the short run, where the input mix of energy (and other inputs) cannot be altered.

Previously, I–O models have been used intensively in Japan to estimate the change in commodity prices due to a carbon tax. In most of these analyses, the focus is directed toward the entire economy or final consumption of goods and services. The competitiveness issue for the Japanese industry under carbon prices, however, has not been examined in detail.

For example, Sugimoto (1995) uses the projected I–O table for 1989 and applies a carbon tax of \22,000/t-C (US$220 equivalent). The top three price-increasing industries were electric power, gas, and water supply (12.75 percent); ceramic, stone, and clay products (10.18 percent); and iron and steel (7.01 percent).[1]

Fujikawa (2002) uses the 1995 I–O table and applies a tax rate of \10,000/t-C (US$100). The classification system used in the analysis involves 184 industries. The analysis shows that prices of coal products, petroleum refinery products, steel-related industries, and chemical industries rise disproportionately. In a similar vein, Shimoda and Watanabe (2006) use the 2000 I–O table and apply a tax of \2,400/t-C. They find results similar to those of Fujikawa (2002) using 104 industries.

Nakamura and Kondo (2004) analyze the impact of a carbon tax using the 1995 I–O table. The classification system used in the analysis involves 397 industries and focuses on the overall impacts to the Japanese economy and employment by allowing substitution between

[1] The analysis uses 29 sectors.

domestic and imported goods. Nakamura and Kondo (2004) find that a carbon tax reduces the production of EITE and domestic employment.

Morgenstern et al. (2004) focus on the “actual” burden of carbon pricing and the composition of the total cost increase. Using the1992 U.S. I–O table, they find that EITE industries may face disproportionately higher production costs. As for the decomposition of the total cost increase, they verify that the source cost increase differs with industry (i.e., some industries face high costs due to direct emissions, whereas others face high indirect and intermediate good costs). More recent work by Adkins et al (2012) updates the earlier work and finds similar impacts.

In sum, the disproportionate impact of carbon pricing on energy-intensive industries has repeatedly been verified in Japan and the U.S.. However, previous Japanese studies have not investigated the effects of an exemption or rebating program for EITE industries.

One exception is Japan’s Central Environment Council, whose analysis focuses on the reduction of the price increase due to a tax exemption program for energy-intensive industries (Chuo Kankyo Shingikai 2005). By implementing a tax exemption program, it finds that the price increase is moderated significantly, thereby preserving the competitiveness of energy-intensive industries. The analysis has two major shortcomings: the aggregation of industries and the criteria for exemption. Regarding the first shortcoming, it analyzes 41 industries. The exemption program should include only trade-exposed industries. However, the aggregation of industries would allow many nontrade-exposed industries to be exempted from the carbon price as well. Thus, more disaggregated industrial classification is needed to assess the impact of carbon pricing. The second and more critical shortcoming is related to the criteria identifying the industries eligible for the exemption program. In the analysis, Chuo Kankyo Shingikai (2005) identifies industries by broad qualitative criteria without regard to their true energy intensity or trade exposure. For example, coal and coke used by the iron and steel industries is exempted from taxation altogether, as is heavy fuel oil used by the agricultural, forestry, and fishery industries. Furthermore, energy-intensive manufacturing can receive a rebate of up to 50 percent of the total carbon tax payment.[2]

[2] In the report, other exemptions are included, such as a low-income household exemption, cold district household rebates, a small firm exemption, and an exemption of the power industry.

This paper uses updated and quite detailed data to examine the competitiveness issues the Japanese economy may face under carbon pricing regulations. We use the sector-detailed classification (401 sectors) of the 2005 I–O table and adopt an approach similar to that of Morgenstern et al. (2004) to decompose total cost. This method allows us to disentangle the cost increase into three pieces: direct cost, indirect cost,[3] and intermediate good cost. However, we use a different method—based on the concept of embodied environmental burden intensity—to calculate total cost (Nansai et al. 2002). This concept allows us to avoid obtaining negative values when calculating intermediate cost.

Then we compare two sets of criteria—Waxman Markey and E.U.-ETS—to determine which EITE sectors are eligible for the exemption program. We also investigate the extent to which the cost impacts can be dampened if the Waxman Markey bill or E.U.-ETS rebate programs are applied to the Japanese economy.

The remainder of the paper is organized as follows. Section 2 illustrates the model and the methods of analysis. In Section 3, we explain the data. Section 4 presents the results, including the results from the analysis of the rebate programs. Section 5 concludes.

2. Model for the Calculation and Methods for Identifying EITE Industries

In this section, we briefly explain the basic model that we use to calculate the cost increases due to carbon pricing. Then, we explain the two methods used to identify EITE industries (Waxman Markey and the E.U. method). Finally, we explain the simulation method used to estimate the impact of the rebate program on EITE industries.

2.1 Calculating the Carbon Cost Increase[4]

We use the concept of embodied environmental burden emissions intensity to calculate the total cost due to the introduction of carbon pricing (Nansai et al. 2002).[5] This concept allows

[3] Indirect cost is the cost from the use of goods from the following three sectors: (a) electrical power for enterprise use, (b) onsite power generation, and (c) steam and hot water supply.

[4] We assume that the carbon tax or emissions trading will be enforced downstream rather than upstream.

[5] In Morgenstern et al. (2000), some industries had negative intermediate costs. In theory, the introduction of carbon pricing will raise either total cost, indirect cost, or intermediate cost. However, the reduction of costs is unanticipated. We use the concept of embodied environmental burden emissions intensity because it is consistent with theory.

for the calculation of total emissions, consisting of direct emissions, indirect emissions from electricity and hot water/steam usage, and emissions embodied in intermediate goods.

We start by calculating total CO_2 emissions for each industry. Total CO_2 emissions refer to the sum of direct and indirect emissions from the usage of electricity and hot water/steam. Direct emissions are calculated by

$$Emission_j^{DC} = \sum_{f \in DC} e_f \theta_{jf} Y_{jf} \tag{1}$$

Here, e_f is the CO_2 emissions coefficient for fuel f, θ_{fj} is the combustion ratio of fuel f for industry j, and Y_{jf} is the amount of fuel f purchased by industry j. We assume that 13 types of fossil fuels are used by each industry.[6, 7] Caution is needed with this calculation for three industries: electricity for enterprise use, onsite power generation, and hot water/steam. The direct emissions of these industries are captured by the indirect emissions of other industries because the users of electricity and/or hot water/steam are responsible for the emissions from these three industries. Double counting of CO_2 emissions is avoided by adjusting the direct emissions of these industries to zero.

Next, the indirect emissions are calculated as

$$Emission_j^{INDC} = \sum_{f \in INDC} e_f Q_{jf} \tag{2}$$

Here, e_f is the CO_2 emissions coefficient for three types of energy and Q_{jf} is the amount of energy f consumed by industry j.

The sum of direct and indirect emissions, divided by total domestic production, gives the amount of CO_2 emitted to produce one yen's worth of commodity, or simply

[6] The 13 types of fossil fuels used in the analysis are: coal, crude oil, natural gas, heavy fuel oil A, heavy fuel oils B and C, kerosene, diesel oil, gasoline, jet fuel, naphtha, liquefied petroleum gas, gas supply, and coke.

[7] The consumption of fossil fuels is divided into two categories: combustion and feedstock. Combustion refers to fossil fuels consumed as an energy source, with resultant CO_2 emissions. On the other hand, feedstock refers to the consumption of fossil fuels as an input in the production of other goods. For example, naphtha consumed by the chemical fertilizer sector is used as a raw material to produce chemical products. Thus, in the analysis, we use combusted fossil fuels to estimate equation 1.

$$Emission\ Intensity_j = \frac{Emission_j^{DC} + Emission_j^{INDC}}{Total\ Domestic\ Production_j} \quad (3)$$

The product of emissions intensity and the carbon price (tax rate) gives the increase in cost per unit of output. The total cost increase due to the carbon price is calculated using this product.

Next, the total cost is constituted of "direct" payment, the usage of electricity and hot water/steam, and "indirect" payment of carbon pricing through increased prices of inputs (intermediate goods). The I–O table reports this relationship among industries in the inter-industry transaction table. Using the simple quantity determination model, the well-known relationship between final demand and domestic production is

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{F} \quad (4)$$

where $\mathbf{X}$ is the vector of total production, $\mathbf{I}$ is the identity matrix, $\mathbf{A}$ is the input coefficient matrix, and $\mathbf{F}$ is the vector of final demand. $(\mathbf{I} - \mathbf{A})^{-1}$ is known as the Leontief inverse. The Leontief inverse represents how much input is needed to produce an additional unit of output for industry i. For example, to produce one unit[8] of steel, inputs such as iron ore, coal, electricity, etc, are needed. We can calculate the total CO_2 emitted in the production of an extra unit of output using the Leontief inverse.

The input needed to produce one unit of i industry's good $\mathbf{Z}$ is calculated as

$$\mathbf{Z}^i = (\mathbf{I} - \mathbf{A})^{-1} \cdot \mathbf{i}_i \quad (5)$$

where $\mathbf{i}_i$ equals one for industry i and zero otherwise. The inner product of equation 3 and equation 5 gives the per-output total CO_2 emitted in the production of an additional \1 worth of product i or

$$\text{Total Emission}^{\text{i}} = \mathbf{Emission\ Intensity} \bullet \mathbf{Z}^i \quad (6)$$

The concept of embodied environmental burden is expressed by equation 6. Implementing a carbon price, t, will increase the total cost per output depending on the size of per-output total

[8] The Japanese I–O table lists values (quantity times price) in \1 million. Thus, one unit can be considered \1 million worth of goods.

emissions. Industries relying on energy-intensive commodities (i.e., those with higher total emissions) will bear higher per-output total costs and vice versa.

$$Cost^{i} = \mathrm{t} \cdot \mathrm{Total\,Emission}^{\mathrm{i}} \tag{7}$$

This formulation depicts the total cost of carbon pricing to produce one unit of industry i 's commodity. In other words, this value is the percentage of total cost increase per unit of output.

Finally, the cost increase for industry j is the sum of direct cost $COST_j^{DC}$, indirect cost, $COST_j^{INDC}$, and intermediate good cost, $COST_j^{INT}$.[9]

$$COST_j = COST_j^{DC} + COST_j^{INDC} + COST_j^{INT} \tag{8}$$

The first type of cost imposed by carbon pricing is the direct cost. The direct cost is the cost that the industry directly bears as a result of the combustion of fossil fuels. This is calculated using the formula

$$COST_j^{DC} = t \cdot \frac{\sum_{f \in DC} e_f \theta_{jf} Y_{jf}}{Total\ Domestic\ Production_j} \tag{9}$$

The second type of cost is the indirect cost, i.e., the cost from the use of goods from the following three sectors: electrical power for enterprise use, onsite power generation, and steam and hot water supply. Indirect cost is calculated as

$$COST_j^{INDC} = t \cdot \frac{\sum_{f \in INDC} e_f Q_{jf}}{Total\ Domestic\ Production_j} \tag{10}$$

We assume that the electricity used by every industry has the same carbon emissions intensity. In other words, the emissions coefficient for electricity does not differ with industry. Morgenstern et al. (2004) use different emissions coefficients for electricity usage for each industry. For example, the aluminum industry, whose facilities are often located near hydro-power plants, uses more hydro-generated electricity than other industries.

The total cost, direct cost, and indirect cost can be calculated directly from the available data. Unfortunately, the intermediate good cost cannot be easily derived from the available data.

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[9] We calculate all values as ratios of cost to \1 million of domestic production.

However, using equation 7, we can obtain the intermediate good cost. In other words, the intermediate good cost is the residual of total cost minus direct and indirect cost.

2.2 Waxman–Markey Bill

H.R. 2454 addresses the competitiveness issue by rebating cap-and-trade induced cost increases for EITE industries. Based on the six-digit North American Industrial Classification System (NAICS), industries eligible for the rebate (free allocation) must satisfy one of four criteria: (a) energy intensity greater than 5 percent and trade intensity is greater than 15 percent, (b) GHG intensity greater than 5 percent and trade intensity greater than 15 percent, (c) energy intensity greater than 20 percent, or (d) GHG intensity greater than 20 percent.[10] Each criterion is calculated as

(a) Energy Intensity = $\frac{(Electricity\ Cost)+(Fuel\ Cost)}{Value\ of\ Shipments} \geq 5\%$ and,

Trade Intensity = $\frac{(Total\ Import)+(Total\ Export)}{(Value\ of\ Shipments)+(Total\ Import)} \geq 15\%$

(b) GHG Intensity = $\frac{\$20 \times (Greenhouse\ Gas\ Emissions)}{Value\ of\ Shipments} \geq 5\%$ and,

Trade Intensity = $\frac{(Total\ Import)+(Total\ Export)}{(Value\ of\ Shipments)+(Total\ Import)} \geq 15\%$

(c) High Energy Intensity = $\frac{(Electricity\ Cost)+(Fuel\ Cost)}{Value\ of\ Shipments} \geq 20\%$

(d) High GHG Intensity = $\frac{\$20 \times (Greenhouse\ Gas\ Emissions)}{Value\ of\ Shipments} \geq 20\%$

2.3 E.U.-ETS Provision of EITE Industries

The E.U.-ETS is in the transition stage, moving from allocating emissions permits by grandfathering to auction. In this transition, the E.U.-ETS is planning to give free allocations to EITE industries based on industry-wide benchmarks.

[10] The proposed bill specifies that the figures for energy, GHG, and trade intensities are to be rounded to the nearest whole number.

The EITE industries are identified by combining two indices—carbon intensity and trade intensity—to make three criteria. The calculation of each index is

(a) Carbon Intensity = $\frac{30EUROs \times (Direct\ Emission + Indirect\ Emission)}{Gross Value\ Added} \geq 5\%$ and,

Trade Intensity = $\frac{(Total\ Import) + (Total\ Export)}{(Value\ of\ Turnover) + (Total\ Import)} \geq 10\%$

(b) High Carbon Intensity = $\frac{30EUROs \times (Direct\ Emission + Indirect\ Emission)}{Gross Value\ Added} \geq 30\%$

(c) High Trade Intensity = $\frac{(Total\ Import) + (Total\ Export)}{(Value\ of\ Turnover) + (Total\ Import)} \geq 30\%$

The largest difference between the E.U. criteria and those of Waxman Markey is the relatively greater importance of trade intensity in the E.U. system. Other differences are: the price of carbon used in the calculation, the inclusion of energy intensity, and the denominator of carbon intensity and GHG intensity.

2.4 Simulation of Rebate Program

The industries identified as EITE by the Waxman Markey or E.U. criteria are subject to special treatment for compliance. Under Waxman Markey, firms would be able to receive rebates according to direct and indirect emissions. The eligible industries are estimated to receive 85 percent rebates. At the same time, the European Union is planning to allocate free emissions permits covering direct emissions only. However, the allocation will be based on benchmarks that are currently under calculation. Thus, modeling the E.U.-ETS is very difficult at this time.

For simplicity, we assume that the industries identified by the Waxman Markey criteria will receive an 85 percent rebate or pay a carbon price of \2,200/t-C for direct and indirect emissions. As for the E.U. simulation, we assume an 85 percent rebate for direct emissions only (i.e., a carbon price of \2,200 t-C for direct emissions and a carbon price of \14,667 t-C for indirect emissions).

The change in carbon price for EITE industries will affect other industries by reducing the price of intermediate goods. Thus, the rebate program will affect other industries that are not directly covered by the program.

3. Data

This section briefly describes the data used in the analysis. Specifically, we use the 2005 Japanese I–O table and the Table of Values and Quantities (TVQ) for the analysis.

3.1 Japanese I–O Table

The Japanese baseline I–O table is published every five years by the Ministry of Internal Affairs and Communications. The 2005 I–O table, published in 2009, is the most recent. Projections of the I-O tables for other years (somewhat simplified) are available from the Ministry of Economy, Trade, and Industry (MEITI).

The key difference between the baseline and projected/simplified I–O tables is one of scope: the baseline and projected I–O tables use a very fine industrial classification with 407 industries and 520 commodities.[11] In contrast, the simplified I–O table uses 186 industries and 186 commodities. More importantly, the baseline I–O table includes important tables, such as the TVQ, corresponding tables, and the employment table. However, the projected and simplified I–O tables do not include these key tables.

An important feature of the Japanese I–O table is the treatment of by-products and scrap. The Japanese I–O table is constructed using the Stone method. In short, the by-products and scrap are listed as negative inputs for each industry. Another feature is the number reported in the interindustry transaction table. The numbers listed are values (quantity times price) in \1 million. Furthermore, the “make” and “use” matrices are not published in the Japanese I–O table.

Concerning the data used in the analysis, the following data are collected from the I–O table: interindustry transaction table, final demand, domestic production, total imports, total exports, and value added. The first three are used in calculating the total cost increase due to carbon pricing. The remaining three are used to identify the EITE industries.

3.2 Tables of Values and Quantities

The quantity of inputs purchased by each industry is reported in the TVQ, which identifies two types of energy: combustible energy and noncombustible energy. Combustible energy refers to energy that contains carbon that is released when the energy source (i.e., fossil fuels) is combusted. Noncombustible energy refers to energy whose use does not release carbon; instead, the production of noncombustible energy releases carbon into the atmosphere.

The TVQ reports 13 types of combustible energy: coal, crude oil, natural gas, heavy fuel oil A, heavy fuel oil B and C, kerosene, diesel oil, gasoline, jet fuel, naphtha, liquefied petroleum

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[11] The finest industrial classification is referred to as the base table.

gas, gas supply, and coke. In contrast, the TVQ lists three noncombustible energy sources: electric power for enterprise use, onsite power generation, and steam and hot water supply.

The direct CO_2 emissions can be calculated using information from the TVQ. Similarly, indirect CO_2 emissions are calculated by using the emissions coefficients and the amount of purchased noncombustible energy.

3.3 The Structural Survey of Energy Consumption in Commerce and Manufacturing

Ho et al. (2008) point out that the combustion ratio differs among fuels and industries. Therefore, adjustment of the input of fossil fuels is needed. The I–O table does not divide inputs into combustible and feedstock types. Therefore, data from other sources are needed. We rely on *The Structural Survey of Energy Consumption in Commerce and Manufacturing* (METI) for feedstock ratios for each industry. This survey collects data for energy consumption covering the entire manufacturing sector. In the survey, energy consumption is categorized by the combustion of fossil fuels and by feedstock. Using this information, the combustion ratio for each industry is calculated.

One potential problem with this survey involves the nature of the industrial classifications. This survey uses the industrial classification used in the *Census of Manufacturers* (METI). The industry classification used for this survey differs from that used for the I–O table. This is because METI uses a unique classification for industries.[12] The I–O table provides a corresponding table for the two different industry classifications. Thus, the industrial classification does not create a problem in the calculation.

Another potential problem is the availability of *The Structural Survey of Energy Consumption in Commerce and Manufacturing,* which has been discontinued since 2001. Thus, recent figures are unavailable. The *Yearbook of the Current Survey of Energy Consumption* has been conducted since 1981 as a complement to The *Structural Survey of Energy Consumption in Commerce and Manufacturing*. However, the manufacturing industries included in this survey are quite limited. Therefore, data covering the entire manufacturing sector are unavailable. As a consequence, we assume that the combustion ratio for each industry has not changed since 2001.

[12] METI also uses a unique classification for commodities. The I–O table provides the corresponding table for commodities for the same reason.

4. Results

In this section, we present the results of the three calculations of percentage cost increase. First, we present the results for the baseline model or the model without any rebating program. Then, we present the results for the W.M. rebate program followed by the results for the E.U. rebate program. Overall, our analysis replicates the total CO_2 emissions for the Japanese economy reasonably well.[13]

4.1 Baseline Model

The impact of a carbon tax of \14,667/ t-C is estimated to increase final demand expenditure by \5.351 trillion (US$53.5 billion). This is an increase of 0.551 percent of total domestic production or 1.058 percent of the gross domestic product.

Table 1 displays the estimated percentage increase in cost for the top 20 industries. Among others, pig iron, crude steel, and cement face major cost increases. Pig iron, ranked first in the list, faces a cost increase as high as 29.9 percent. Thus, carbon pricing may have significant impacts on the competitiveness of the industry. In the case of industrial soda chemicals, ranked last among the top 20, the cost increase is less than 5.5 percent. Because we have 401 sectors in our analysis, the cost increase is less than 5.5 percent for most industries.[14] Figure 1 shows the "uneven" burden of carbon pricing. The majority of industries face total cost increases of less than 5 percent. Thus, only a few sectors will face severe total cost increases.

Table 1 also illustrates the breakdown of the cost increase according to the sources of cost increase. The column with "direct cost" shows the cost increase from fossil fuel combustion. The column with "indirect cost" is for increases from electricity and hot water/steam. The column with "intermediate good cost" is from the nonenergy intermediate goods. The source of the cost increase varies by industry. For example, most of the cost increase in pig iron arises

[13] The model presented in Section 2 has one possible shortcoming. The energy sources are limited to 13 major sources. Thus, other types of fossil fuels, such as coke oven gas, blast furnace gas, petroleum coke, and so on, are excluded. As a consequence, the total CO_2 emissions from the entire Japanese economy can be considered underestimated. The model used in this paper yields an estimate of CO_2 emissions of 1,337.8 million tons. The Ministry of the Environment reports that emissions from fossil fuel combustion is 1,290.6 million tons, whereas Nansai and Moriguchi (2009) and Nakano (2009) estimate total CO_2 emissions based on the I–O table as 1,344.2 million tons and 1,399.6 million tons, respectively. In sum, the estimate of CO_2 emissions in this model falls between the estimate announced by the Japanese government and calculations based on the I–O table. Therefore, the underestimate appears to be negligible.

[14] The average increase in total cost is estimated at 1.999 percent.

from the increase in direct cost—fuel combustion. At the same time, for the compressed gas and liquefied gas case, the increase mainly arises from indirect cost—that is, electricity input. Moreover, in the case of the steel pipes and tubes sector, most of the cost increase arises from the increase in the intermediate good cost. Thus, if we focus only on fossil fuel combustion, we will draw incomplete conclusions.

4.2 Simulation of a Waxman Markey-Type Rebate Program[15]

The Japanese industries eligible for the type of rebate program proposed in the United States are listed in Table 2. Out of 240 manufacturing industries, 23 satisfy the Waxman Markey criteria.[16] The pulp, chemical fertilizer, salt, methane derivatives, and ferro alloys industries are identified using the GHG and trade intensities, whereas the cement and pig iron industries satisfy the high GHG intensity criterion. All 23 industries satisfy the energy intensity and trade intensity or the high energy intensity criteria. Thus, the energy intensity criterion is very important in identifying EITE industries. These industries account for approximately 16 percent of total Japanese emissions in 2005. The magnitude of economic activity of these 23 industries is 1.02 percent of national production, 0.63 percent of value added, and 0.31 percent of employment.

For comparison, Houser (2009) analyzes the four Waxman Markey criteria and finds that, out of 565 U.S. industries, 35 are eligible for the cost rebates.[17] Of the 35 industries, 26 are manufacturing, 4 are mining, and 5 are agricultural industries. The CO_2 emissions of these industries in 2006 made up 9.4 percent of total U.S. CO_2 emissions. Although the industrial classification in Japan differs from that of the United States, the number of industries identified is similar.

The listed sectors are entitled to a rebate of 85 percent of total carbon costs under the W.M. bill. Table 3 illustrates the cost increase by sector after the rebate program. For simplicity, we assume that, as a result of the rebate, the eligible industries face a cost increase of \2,200/t-C rather than \14,667/t-C. Compared with Table 1, one can observe large changes in cost increases and rankings. Once the program is implemented, gas supply ranks number one in cost increase.

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15 Appendix A presents the actual calculation method used to identify EITE industries.

16 The total number of industries used in this paper is 401; of those, 242 are manufacturing industries. However, the W.M. bill specifically exempts the petroleum refining industry. To be consistent with the W.M. bill, we therefore exclude the petroleum products and coal products industries from the list.

17 The carbon cost used in the analysis was $110 t-C rather than the $73.3 t-C specified in the W.M. bill.

As a result of the rebate program, the cost increase for the pig iron industry declines to 5.63 percent from 29.90 percent in Table 1.

In Figure 2, the distribution of the total cost increase is not as dispersed as in Figure 1. This is because the rebate program reduces the carbon price impact for the entire economy. In other words, industries directly benefit from the reduced payment of the carbon price. Other industries also benefit indirectly from lower intermediate costs.

Table 4 shows how the rebate program mitigates the impacts of carbon pricing on costs for sectors eligible for the rebate program. The sixth column displays the cost reduction due to the rebate. For pig iron, the cost declines by 81.18 percent. For ferro alloys, the rebate program reduces the cost by 72.55 percent. For inorganic pigment, however, the cost reduction is 47.77 percent. This difference arises from variation in the sources of cost increases (see Table 1). For the sectors whose cost increases are mainly due to direct cost and/or indirect cost, the rebate program has relatively large impacts. In contrast, for the sectors whose cost increases are mainly due to the intermediate good cost, the rebate program has relatively small impacts.

4.3 E.U.-ETS Criteria

For comparison, we use the E.U.-ETS criteria to identify EITE industries (Table 5). In contrast to U.S. criteria, more sectors are identified as EITE; specifically, 122 industries are eligible for the rebate using E.U.-type criteria.[18] Eighteen industries are found on both the U.S. and E.U. lists. Five industries are found only on the U.S. list: sugar, industrial soda chemicals, compressed gas and liquefied gas, pottery, china and earthenware, and clay refractories. These industries are not found on the list using E.U. criteria because the energy intensity for each of these industries is greater than 5 percent. Thus, the list using the Waxman Markey criteria is not a complete subset of the E.U. list.[19]

Table 6 shows the sectors facing the highest ratio of cost increases under the E.U.-ETS rebate program. As before, gas supply is number one for total cost increase. Interestingly, the cost increases under the E.U. rebate program (Table 6) are relatively similar to those under the

[18] The European Union has reported that 146 out of 258 industries would be eligible for rebates using the four-digit statistical classification of economic activities in the European Community (NACE).

[19] In Appendix B, we briefly break down the reduction in total cost by the 5 industries specific to the U.S. list, the 18 industries both found on the U.S. and E.U. lists, and the 104 industries specific to the E.U. list.

proposed U.S. rebate program (Table 3), even though the number of covered industries is greater for the E. U. than for the U.S.

Figure 3 shows the distribution of total cost increases using the E.U. rebate program. The distribution of total cost increase is not as dispersed as in Figure 1; rather the distribution appears quite similar to the U.S. case (Figure 2).

In Table 7, we list the 10 industries that experience the greatest cost reduction with the E.U. rebate program. This rebate program could have significant impacts for energy-intensive industries such as pig iron and cement.

Table 8 summarizes the simulation results. With the E.U.-ETS criteria, the increase in cost is 1.33 percent, on average, whereas it is 1.29 percent with Waxman Markey criteria. Thus, although the differences are small, the Waxman Markey criteria are slightly more effective on average than the E.U.-ETS criteria in reducing the cost impacts. However, the minimum increase and maximum increase are slightly lower for the E.U. simulation. From the simulation results, the differences between the two rebate programs are clarified. The E.U. rebate program includes a wide range of industries with coverage for direct emissions only compared to the U.S. program, which includes a smaller number of industries with coverage for both direct and indirect emissions costs.

5. Conclusion

This study examines the impacts of carbon pricing on the Japanese economy in the short run using a detailed analysis based on the most recent I–O table. A major benefit of the I-O approach is that it allow us to distinguish the cost impacts associated with direct fossil fuel combustion as opposed to the use of electricity or intermediate goods.

We find that the cost impacts of carbon pricing vary dramatically by sector. We also find that the source of the cost increase differs by industry. For some industries, the fossil fuel price increases have the biggest impacts. For others, cost increases arise from increases in the prices of electricity and intermediate goods. We also find that carbon pricing can have significant impacts on some industries, such as pig iron or crude steel (converters). These industries face particular disadvantages in international competition because they compete so intensely with producers in nations without stringent carbon regulations.

One approach for addressing the competitiveness issues for the EITE industries is to introduce rebate program similar to the mechanisms used in the E.U. and included in the U.S. legislation which passed the House of Representatives in 2009 (H.R. 2454). Based on our I-O model simulations, we find that the number of Japanese industries eligible for the rebates is substantially larger under the E.U. than the U.S. approaches. At the same time, the average rebates are smaller under the E.U. system. When the average cost increase and rebates are netted out, the two systems yield roughly similar average results: 1.33 percent with the E.U.-ETS criteria versus 1.29 percent with Waxman Markey criteria. Thus, although the average differences are small, the Waxman Markey criteria are slightly more effective on average than the E.U.-ETS criteria in reducing the cost impacts. Overall, the E.U. rebate program includes a wide range of industries with coverage for direct emissions only compared to the U.S. program, which includes a smaller number of industries with coverage for both direct and indirect emissions costs.

These results are best thought of as upper bound estimates of the cost increase. Our analysis focuses on the short run, before adjustments are possible. If prices of goods increase due to carbon pricing, both consumers and producers may substitute with other inputs. Hence, the cost increase with the CO_2 prices of \4,000 will likely be smaller than the results presented herein.

Also, in reality, the E.U. rebate is likely to be smaller than that used in our simulation.[20] In this analysis, we hypothetically used the Waxman Markey style rebate program for industries chosen with E.U. criteria. In Phase III of E.U.-ETS, as yet undefined benchmarks will be used to compensate for EITE industries. We could not use the benchmark method because the specifics are unknown at this time.

Future research should focus on alternative definitions of the eligibility criteria used for including industrial sectors in the rebate program. Because of different energy use patterns between the U.S. and Japan, we find that relatively few Japanese industries are eligible for the rebate program under the Waxman Markey energy intensity criteria. Relaxed criteria for energy intensity would potentially increase the number of eligible industries substantially.

[20] Furthermore, indirect cost will probably be covered in the rebate program. However, at the present stage of negotiations, it is very difficult to estimate the coverage rates because the rates will differ among countries.

Figures and Tables

Figure 1. Distribution of the Percentage of the Total Cost Increase (Baseline Case)

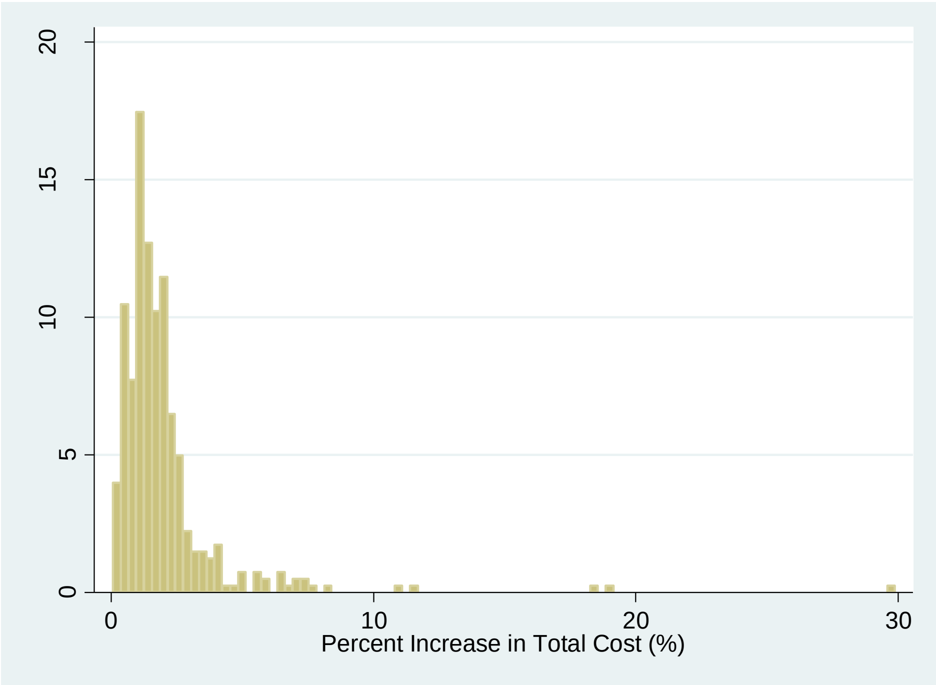

Figure 2. Distribution of the Percentage of the Total Cost Increase (W.M. Rebate Case)

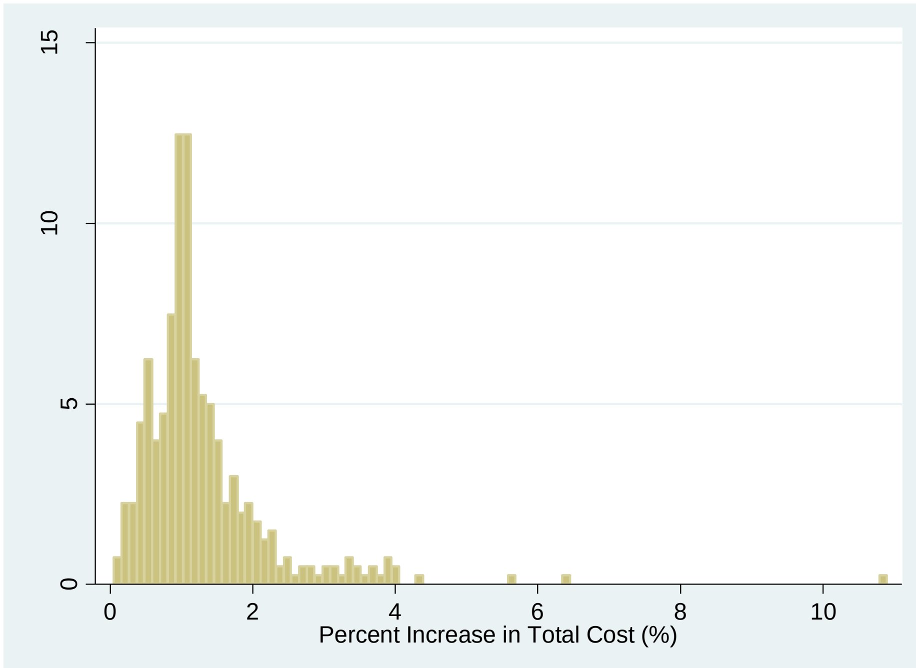

Figure 3. Distribution of the Percentage of the Total Cost Increase (E.U. Rebate Case)

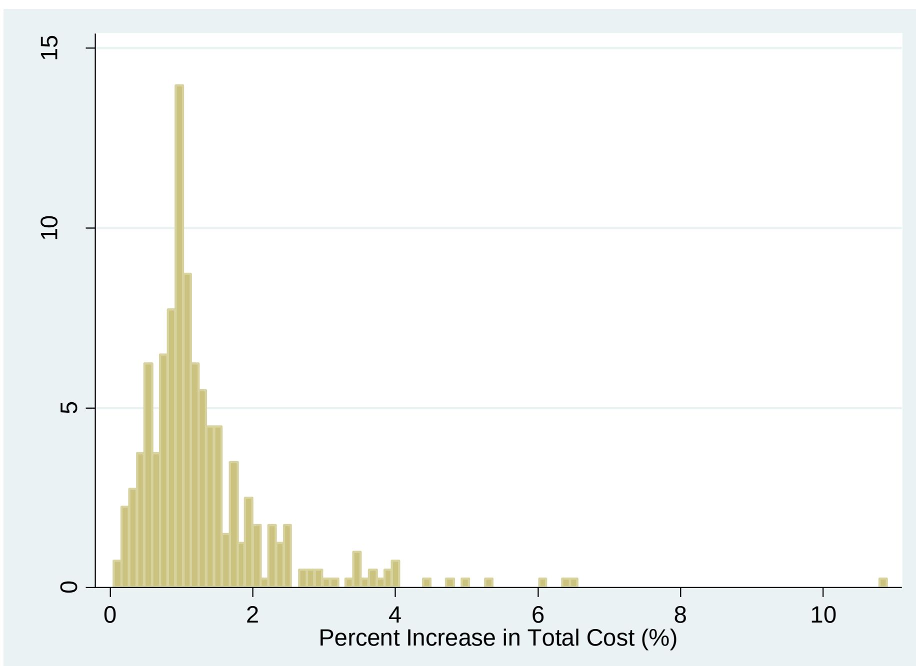

Table 1. Percentage Increase in Cost without Rebates (Top 20 Industries)

Industry	Total Cost	Rank	Direct Cost	Rank	Indirect Cost	Rank	Intermediate Cost	Rank
Pig iron	29.90%	1	27.86%	1	0.49%	37	1.56%	109
Crude steel (converters)	18.95%	2	0.50%	56	0.16%	171	18.29%	1
Cement	18.43%	3	15.17%	2	2.10%	3	1.16%	187
Hot rolled steel	11.43%	4	0.34%	72	0.10%	276	11.00%	2
Gas supply	11.06%	5	9.87%	3	0.15%	175	1.03%	227
Cold-finished steel	8.35%	6	0.20%	115	0.55%	33	7.59%	3
Steel pipes and tubes	7.69%	7	0.14%	157	0.12%	233	7.44%	4
Cast and forged materials (iron)	7.46%	8	1.00%	34	1.36%	10	5.10%	8
Ferro alloys	7.37%	9	4.16%	4	1.83%	5	1.39%	142
Chemical fertilizer	7.17%	10	3.58%	6	0.41%	46	3.19%	18
Iron and steel shearing and slitting	7.06%	11	0.03%	329	0.13%	218	6.91%	5
Compressed gas and liquefied gas	6.67%	12	0.13%	171	5.33%	1	1.22%	174
Coated steel	6.57%	13	0.11%	183	0.37%	54	6.09%	6
Crude steel (electric furnaces)	6.50%	14	0.32%	78	1.81%	6	4.37%	10
Ocean transport	6.45%	15	3.24%	9	0.00%	397	3.21%	17
Methane derivatives	5.92%	16	3.16%	10	0.33%	70	2.43%	26
Cast iron pipes and tubes	5.87%	17	1.74%	17	0.81%	21	3.32%	15
Ready mixed concrete	5.57%	18	0.10%	196	0.10%	262	5.37%	7
Pulp	5.49%	19	3.38%	8	0.94%	15	1.17%	183
Industrial soda chemicals	5.48%	20	0.68%	49	3.12%	2	1.68%	92

Table 2. Industries Identified as EITE by the Waxman–Markey Criteria

Industry	Trade Intensity	CO_2 Intensity	Energy Intensity	National Production	Value Added	Employment	Direct CO_2 Emission
Sugar	15.43%	2.46%	6.23%	0.032%	0.018%	0.010%	0.078%
Animal oils and fats	40.29%	2.12%	6.90%	0.003%	0.002%	0.001%	0.008%
Pulp	28.06%	7.70%	12.77%	0.058%	0.014%	0.007%	0.454%
Chemical fertilizer	25.56%	7.57%	13.28%	0.032%	0.020%	0.008%	0.231%
Industrial soda chemicals	6.46%	4.48%	26.20%	0.054%	0.031%	0.005%	0.371%
Inorganic pigment	35.28%	1.05%	5.24%	0.031%	0.017%	0.008%	0.042%
Compressed gas and liquefied gas	2.36%	5.58%	29.06%	0.030%	0.016%	0.006%	0.293%
Salt	43.58%	7.55%	7.65%	0.005%	0.005%	0.003%	0.036%
Other industrial inorganic chemicals	44.51%	2.10%	6.63%	0.081%	0.056%	0.022%	0.182%
Synthetic rubber	31.57%	2.84%	8.17%	0.054%	0.028%	0.007%	0.174%
Methane derivatives	49.92%	6.66%	8.40%	0.014%	0.007%	0.003%	0.090%
Synthetic dyes	102.34%	2.21%	8.18%	0.004%	0.003%	0.001%	0.010%
Rayon and acetate	54.01%	3.90%	8.19%	0.007%	0.004%	0.002%	0.029%
Synthetic fibers	44.52%	3.10%	7.35%	0.044%	0.028%	0.014%	0.156%
Glass fiber and glass fiber products, n.e.c.	27.31%	3.69%	13.09%	0.021%	0.015%	0.010%	0.093%
Other glass products	42.68%	2.49%	6.05%	0.089%	0.087%	0.055%	0.225%
Cement	8.23%	32.43%	25.77%	0.042%	0.025%	0.009%	1.307%
Pottery, china and earthenware	27.97%	2.58%	6.84%	0.075%	0.065%	0.079%	0.203%
Clay refractories	26.20%	2.11%	6.66%	0.023%	0.018%	0.013%	0.056%
Carbon and graphite products	46.61%	2.53%	7.25%	0.030%	0.020%	0.012%	0.090%
Pig iron	1.87%	56.20%	36.57%	0.222%	0.111%	0.018%	11.411%
Ferro alloys	60.74%	10.15%	13.89%	0.027%	0.019%	0.003%	0.288%
Magnetic tapes and discs	63.44%	1.42%	6.20%	0.042%	0.024%	0.011%	0.079%
Total	-	-	-	1.018%	0.632%	0.309%	15.906%

Table 3. Percentage Increase in Cost after Rebate (W.M. Criteria, Top 20 Industries)

Industry	Total Cost	Rank	Direct Cost	Rank	Indirect Cost	Rank	Intermediate Cost	Rank
Gas supply	10.90%	1	9.87%	1	0.15%	157	0.87%	161
Ocean transport	6.38%	2	3.24%	4	0.00%	397	3.14%	2
Pig iron	5.63%	3	4.18%	2	0.07%	289	1.38%	42
Crude steel (converters)	4.33%	4	0.50%	42	0.16%	153	3.67%	1
Coastal and inland water transport	4.04%	5	3.51%	3	0.04%	345	0.50%	302
Self-transport by private cars (passengers)	4.02%	6	3.13%	5	0.01%	382	0.88%	154
Self-transport by private cars (freight)	3.92%	7	3.08%	6	0.02%	374	0.81%	187
Crude steel (electric furnaces)	3.89%	8	0.32%	64	1.81%	2	1.76%	15
Cast and forged materials (iron)	3.88%	9	1.00%	22	1.36%	6	1.52%	35
Other structural clay products	3.82%	10	2.34%	9	0.50%	25	0.98%	111
Other non-metallic ores	3.73%	11	1.64%	13	0.92%	11	1.17%	74
Cast iron pipes and tubes	3.64%	12	1.74%	12	0.81%	13	1.09%	87
Cement	3.54%	13	2.27%	10	0.32%	61	0.95%	123
Steam and hot water supply	3.52%	14	0.00%	397	1.46%	4	2.06%	10
Hot rolled steel	3.46%	15	0.34%	58	0.10%	263	3.03%	3
Sewage disposal**	3.36%	16	1.41%	17	1.23%	8	0.72%	237
Aliphatic intermediates	3.34%	17	1.03%	18	0.32%	60	2.00%	12
Marine fisheries	3.32%	18	2.77%	7	0.00%	394	0.54%	294
Cold-finished steel	3.22%	19	0.20%	101	0.55%	23	2.47%	5
Lead and zinc (inc. regenerated lead)	3.20%	20	0.34%	57	1.50%	3	1.36%	44

Table 4. Reduction in Cost before and after the W.M. Rebate Program

Industry	Before Rebate		After Rebate		Cost Reduction
	Total Cost	Rank	Total Cost	Rank	(%)
Pig iron	29.90%	1	5.63%	3	81.18%
Cement	18.43%	3	3.54%	13	80.77%
Compressed gas and liquefied gas	6.67%	12	1.53%	95	77.05%
Industrial soda chemicals	5.48%	20	1.33%	134	75.82%
Chemical fertilizer	7.17%	10	1.79%	69	75.08%
Salt	5.01%	23	1.25%	146	75.08%
Ferro alloys	7.37%	9	2.02%	51	72.55%
Pulp	5.49%	19	1.53%	96	72.20%
Methane derivatives	5.92%	16	1.81%	67	69.49%
Rayon and acetate	4.10%	29	1.30%	139	68.24%
Sugar	2.84%	55	1.01%	230	64.40%
Glass fiber and glass fiber products, n.e.c.	3.75%	37	1.35%	131	64.07%
Carbon and graphite products	2.82%	56	1.06%	200	62.34%
Other glass products	2.43%	79	0.96%	257	60.69%
Other industrial inorganic chemicals	2.89%	53	1.18%	163	59.20%
Pottery, china and earthenware	2.54%	69	1.04%	215	59.12%
Animal oils and fats	2.55%	67	1.08%	190	57.74%
Clay refractories	2.57%	66	1.10%	185	57.28%
Synthetic rubber	3.13%	47	1.41%	116	54.74%
Synthetic fibers	3.60%	40	1.68%	81	53.33%
Synthetic dyes	2.91%	52	1.39%	119	52.18%
Magnetic tapes and discs	2.40%	84	1.23%	149	48.78%
Inorganic pigment	2.54%	70	1.33%	135	47.77%

Table 5. Industries Identified as EITE by the E.U.-ETS Criteria

Industry	Trade Intensity	CO_2 Intensity	Domestic Production	Value Added	Employee	CO_2 Emissions
Slaughtering and meat processing	42.10%	0.05%	0.16%	0.01%	0.03%	0.00%
Frozen fish and shellfish	46.59%	0.73%	0.14%	0.08%	0.06%	0.06%
Other processed seafood	30.43%	0.52%	0.08%	0.05%	0.06%	0.03%
Bottled or canned vegetables and fruits	46.83%	1.48%	0.01%	0.01%	0.01%	0.01%
Preserved agricultural foodstuffs (other than bottled or canned)	48.48%	0.64%	0.05%	0.03%	0.05%	0.02%
Animal oils and fats	40.29%	4.16%	0.00%	0.00%	0.00%	0.01%
Whiskey and brandy	57.54%	0.58%	0.01%	0.01%	0.00%	0.01%
Fiber yarns	44.27%	2.18%	0.02%	0.01%	0.02%	0.02%
Cotton and staple fiber fabrics (inc. fabrics of synthetic spun fibers)	93.84%	2.83%	0.02%	0.01%	0.02%	0.02%
Silk and artificial silk fabrics (inc. fabrics of synthetic filament fibers)	89.59%	1.74%	0.02%	0.01%	0.03%	0.02%
Woolen fabrics, hemp fabrics and other fabrics	46.28%	1.27%	0.01%	0.01%	0.01%	0.01%
Knitting fabrics	67.26%	1.05%	0.01%	0.01%	0.01%	0.01%
Other fabricated textile products	43.36%	1.25%	0.05%	0.04%	0.06%	0.04%
Woven fabric apparel	56.38%	0.45%	0.11%	0.07%	0.20%	0.03%
Knitted apparel	74.57%	0.64%	0.05%	0.03%	0.09%	0.02%
Other wearing apparel and clothing accessories	63.14%	1.62%	0.02%	0.01%	0.04%	0.02%
Bedding	51.40%	0.41%	0.02%	0.01%	0.02%	0.00%
Other ready-made textile products	33.12%	0.54%	0.05%	0.03%	0.09%	0.02%
Timber	34.16%	0.59%	0.07%	0.05%	0.06%	0.03%
Wooden chips	76.81%	1.33%	0.01%	0.00%	0.00%	0.01%
Pulp	28.06%	34.68%	0.06%	0.01%	0.01%	0.45%
Paper	11.50%	6.01%	0.22%	0.17%	0.05%	0.95%
Chemical fertilizer	25.56%	12.42%	0.03%	0.02%	0.01%	0.23%
Inorganic pigment	35.28%	2.59%	0.03%	0.02%	0.01%	0.04%
Salt	43.58%	7.69%	0.01%	0.01%	0.00%	0.04%
Other industrial inorganic chemicals	44.51%	3.46%	0.08%	0.06%	0.02%	0.18%
Petrochemical aromatic products (except synthetic resin)	31.12%	5.38%	0.10%	0.03%	0.00%	0.13%
Aliphatic intermediates	30.36%	13.72%	0.21%	0.04%	0.01%	0.51%

Cyclic intermediates	72.51%	4.52%	0.16%	0.04%	0.02%	0.18%
Synthetic rubber	31.57%	6.48%	0.05%	0.03%	0.01%	0.17%
Methane derivatives	49.92%	14.58%	0.01%	0.01%	0.00%	0.09%
Oil and fat industrial chemicals	31.51%	1.94%	0.01%	0.01%	0.00%	0.01%
Synthetic dyes	102.34%	4.22%	0.00%	0.00%	0.00%	0.01%
Other industrial organic chemicals	36.98%	2.26%	0.11%	0.06%	0.03%	0.13%
Thermo-setting resins	34.15%	1.31%	0.06%	0.03%	0.01%	0.03%
High-function resins	50.96%	1.07%	0.05%	0.02%	0.01%	0.02%
Other resins	82.38%	1.26%	0.04%	0.02%	0.01%	0.02%
Rayon and acetate	54.01%	7.31%	0.01%	0.00%	0.00%	0.03%
Synthetic fibers	44.52%	5.92%	0.04%	0.03%	0.01%	0.16%
Photographic sensitive materials	79.51%	1.59%	0.06%	0.04%	0.02%	0.06%
Other final chemical products	44.45%	1.54%	0.20%	0.11%	0.06%	0.16%
Tires and inner tubes	56.80%	1.24%	0.11%	0.06%	0.04%	0.08%
Rubber footwear	81.78%	0.98%	0.00%	0.00%	0.01%	0.00%
Plastic footwear	69.56%	1.46%	0.01%	0.01%	0.01%	0.01%
Leather footwear	46.93%	0.30%	0.02%	0.02%	0.03%	0.00%
Leather and fur skins	40.81%	1.28%	0.01%	0.01%	0.01%	0.01%
Miscellaneous leather products	75.55%	0.26%	0.02%	0.02%	0.04%	0.00%
Glass fiber and glass fiber products, n.e.c.	27.31%	6.60%	0.02%	0.02%	0.01%	0.09%
Other glass products	42.68%	2.74%	0.09%	0.09%	0.06%	0.23%
Cement	8.23%	55.69%	0.04%	0.03%	0.01%	1.31%
Carbon and graphite products	46.61%	4.70%	0.03%	0.02%	0.01%	0.09%
Pig iron	1.87%	108.86%	0.22%	0.11%	0.02%	11.41%
Ferro alloys	60.74%	16.11%	0.03%	0.02%	0.00%	0.29%
Steel pipes and tubes	42.87%	1.22%	0.13%	0.05%	0.03%	0.06%
Coated steel	34.77%	2.65%	0.17%	0.06%	0.02%	0.14%
Other iron or steel products	32.78%	1.13%	0.03%	0.02%	0.02%	0.03%
Copper	21.54%	6.18%	0.07%	0.02%	0.00%	0.09%
Aluminum (inc. regenerated aluminum)	54.91%	3.51%	0.06%	0.02%	0.01%	0.08%
Other nonferrous metals	78.84%	2.11%	0.07%	0.03%	0.01%	0.06%
Electric wires and cables	42.86%	0.91%	0.11%	0.06%	0.04%	0.05%
Optical fiber cables	33.35%	2.00%	0.02%	0.01%	0.00%	0.01%
Rolled and drawn copper and copper alloys	39.07%	1.93%	0.06%	0.03%	0.02%	0.05%
Other nonferrous metal products	51.70%	1.95%	0.08%	0.03%	0.02%	0.06%
Turbines	58.06%	0.58%	0.05%	0.04%	0.02%	0.02%
Engines	40.13%	0.59%	0.11%	0.06%	0.03%	0.03%
Pumps and compressors	42.69%	0.45%	0.19%	0.12%	0.11%	0.05%

Machinists' precision tools	53.30%	0.52%	0.09%	0.08%	0.07%	0.04%
Other general industrial machinery and equipment	35.26%	0.45%	0.25%	0.18%	0.17%	0.07%
Machinery and equipment for construction and mining	60.73%	0.47%	0.23%	0.14%	0.08%	0.06%
Chemical machinery	33.70%	0.41%	0.09%	0.07%	0.05%	0.03%
Industrial robots	58.34%	0.54%	0.07%	0.04%	0.03%	0.02%
Metal machine tools	37.41%	0.35%	0.23%	0.16%	0.16%	0.05%
Metal processing machinery	31.17%	0.47%	0.09%	0.07%	0.07%	0.03%
Textile machinery	79.57%	0.46%	0.04%	0.03%	0.04%	0.01%
Food processing machinery and equipment	66.89%	0.25%	0.03%	0.03%	0.03%	0.01%
Semiconductor-making equipment	69.35%	0.50%	0.22%	0.13%	0.10%	0.06%
Vacuum equipment and vacuum components	40.05%	0.41%	0.02%	0.02%	0.01%	0.01%
Other special machinery for industrial use	59.71%	0.39%	0.20%	0.15%	0.11%	0.06%
Bearings	42.19%	1.06%	0.11%	0.08%	0.06%	0.08%
Other general machines and parts	43.79%	0.48%	0.11%	0.10%	0.11%	0.05%
Rotating electrical equipment	48.77%	1.03%	0.11%	0.07%	0.07%	0.07%
Transformers and reactors	51.30%	0.42%	0.02%	0.02%	0.02%	0.01%
Relay switches and switchboards	44.57%	0.39%	0.24%	0.16%	0.17%	0.06%
Wiring devices and supplies	77.80%	0.51%	0.06%	0.04%	0.05%	0.02%
Other industrial heavy electrical equipment	67.43%	0.49%	0.08%	0.05%	0.05%	0.02%
Applied electronic equipment	52.19%	0.16%	0.17%	0.08%	0.06%	0.01%
Electric measuring instruments	100.44%	0.27%	0.10%	0.07%	0.06%	0.02%
Electric bulbs	33.51%	0.78%	0.06%	0.05%	0.03%	0.04%
Batteries	51.84%	1.00%	0.08%	0.04%	0.03%	0.04%
Other electrical devices and parts	89.35%	0.90%	0.15%	0.11%	0.06%	0.09%
Video recording and playback equipment	93.43%	0.30%	0.16%	0.07%	0.06%	0.02%
Electric audio equipment	37.74%	0.70%	0.12%	0.06%	0.05%	0.04%
Radio and television sets	50.60%	0.79%	0.08%	0.03%	0.02%	0.02%
Personal computers	71.16%	0.29%	0.13%	0.05%	0.02%	0.01%
Electronic computing equipment (except personal computers)	83.19%	0.36%	0.04%	0.02%	0.01%	0.01%
Electronic computing equipment (accessory equipment)	92.90%	0.43%	0.21%	0.10%	0.06%	0.04%

Semiconductor devices	96.15%	0.76%	0.11%	0.09%	0.07%	0.06%
Integrated circuits	81.61%	1.79%	0.43%	0.23%	0.17%	0.39%
Electron tubes	40.75%	1.27%	0.03%	0.02%	0.01%	0.02%
Magnetic tapes and discs	63.44%	3.44%	0.04%	0.02%	0.01%	0.08%
Other electronic components	36.82%	1.16%	0.89%	0.42%	0.52%	0.46%
Passenger motor cars	61.48%	0.68%	1.50%	0.38%	0.20%	0.25%
Trucks, buses and other cars	31.68%	0.69%	0.35%	0.09%	0.06%	0.06%
Two-wheel motor vehicles	97.68%	0.58%	0.07%	0.02%	0.01%	0.01%
Steel ships	90.79%	0.92%	0.15%	0.07%	0.05%	0.06%
Ships (except steel ships)	67.90%	0.64%	0.00%	0.00%	0.01%	0.00%
Internal combustion engines for vessels	37.70%	1.82%	0.08%	0.05%	0.03%	0.08%
Rolling stock	36.38%	0.81%	0.05%	0.03%	0.03%	0.02%
Aircrafts	65.15%	1.02%	0.10%	0.08%	0.05%	0.08%
Repair of aircrafts	30.49%	0.64%	0.04%	0.02%	0.01%	0.01%
Bicycles	66.20%	1.81%	0.02%	0.01%	0.01%	0.02%
Camera	59.45%	0.66%	0.03%	0.02%	0.02%	0.01%
Other photographic and optical instruments	90.49%	0.94%	0.07%	0.06%	0.06%	0.05%
Watches and clocks	73.57%	0.79%	0.03%	0.02%	0.02%	0.01%
Professional and scientific instruments	93.06%	0.33%	0.01%	0.01%	0.01%	0.00%
Analytical instruments, testing machine, measuring instruments	43.73%	0.26%	0.15%	0.12%	0.10%	0.03%
Medical instruments	53.05%	0.45%	0.10%	0.07%	0.06%	0.03%
Toys and games	110.17%	0.77%	0.03%	0.01%	0.02%	0.01%
Sporting and athletic goods	41.73%	0.61%	0.04%	0.03%	0.03%	0.02%
Musical instruments	50.95%	0.27%	0.02%	0.02%	0.01%	0.00%
Stationery	53.06%	0.67%	0.03%	0.02%	0.03%	0.01%
Jewelry and adornments	73.86%	0.38%	0.04%	0.03%	0.06%	0.01%
Total	-	-	12.19%	6.37%	5.21%	21.10%

Table 6. Percentage Increase in Cost after Rebate (E.U.-ETS Criteria, Top 20 Industries)

Industry	Total Cost	Rank	Direct Cost	Rank	Indirect Cost	Rank	Intermediate Good Cost	Rank
Gas supply	10.90%	1	9.87%	1	0.16%	175	0.87%	164
Compressed gas and liquefied gas	6.49%	2	0.13%	138	5.33%	1	1.04%	107
Ocean transport	6.38%	3	3.24%	4	0.00%	397	3.14%	3
Pig iron	6.06%	4	4.18%	2	0.49%	37	1.39%	39
Cement	5.34%	5	2.28%	10	2.10%	3	0.96%	125
Industrial soda chemicals	5.02%	6	0.68%	32	3.12%	2	1.21%	62
Crude steel (converters)	4.74%	7	0.50%	42	0.16%	171	4.08%	1
Crude steel (electric furnaces)	4.39%	8	0.32%	58	1.81%	6	2.26%	9
Coastal and inland water transport	4.04%	9	3.51%	3	0.04%	347	0.49%	304
Self-transport by private cars (passengers)	4.02%	10	3.13%	5	0.01%	382	0.88%	159
Cast and forged materials (iron)	3.97%	11	1.00%	22	1.36%	10	1.61%	23
Self-transport by private cars (freight)	3.91%	12	3.08%	6	0.02%	374	0.81%	197
Other structural clay products	3.86%	13	2.35%	9	0.51%	36	1.01%	114
Hot rolled steel	3.76%	14	0.34%	52	0.10%	276	3.33%	2
Other non-metallic ores	3.73%	15	1.64%	13	0.92%	17	1.17%	71
Cast iron pipes and tubes	3.71%	16	1.74%	12	0.81%	21	1.16%	75
Ferro alloys	3.63%	17	0.62%	36	1.83%	5	1.17%	69
Steam and hot water supply	3.52%	18	0.00%	397	1.46%	8	2.06%	11
Paperboard	3.48%	19	0.95%	23	1.05%	14	1.48%	28
Sewage disposal**	3.43%	20	1.41%	16	1.23%	13	0.80%	205

Table 7. Reduction in Cost before and after the Rebate Program (E.U. ETS criteria, Top 10 Industries)

Industry	Before Rebate		After Rebate		Cost Reduction
	Total Cost	Rank	Total Cost	Rank	(%)
Pig iron	29.90%	1	6.06%	4	79.73%
Cement	18.43%	3	5.34%	5	71.04%
Salt	5.01%	23	1.46%	109	70.80%
Chemical fertilizer	7.17%	10	2.33%	42	67.52%
Steel pipes and tubes	7.69%	7	2.72%	30	64.61%
Other iron or steel products	5.13%	21	2.05%	54	59.94%
Methane derivatives	5.92%	16	2.38%	39	59.75%
Steel ships	3.91%	34	1.71%	83	56.18%
Pulp	5.49%	19	2.42%	38	56.02%
Coated steel	6.57%	13	2.95%	26	55.04%

Table 8. Comparison of Total Costs (%)

	Before Rebate	WM Criteria	EU Criteria
Mean	1.999	1.291	1.328
Std. Dev.	2.363	0.954	1.046
Variance	5.582	0.910	1.095
Minimum	0.055	0.049	0.048
Maximum	29.902	10.898	10.896
Skewness	6.491	3.868	3.531

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Appendix A. Calculation of GHG Intensity, Cost Intensity, and Trade Intensity

The availability of Japanese data is very limited. Although there are numerous statistical surveys in Japan, the surveys differ significantly in scope. This creates difficulty in calculating indices used to identify EITE industries. Because disaggregated industrial classification is needed to test the criteria, we use the 2005 I–O table. Furthermore, the I–O table includes all the information needed to calculate the three types of indices.

We need to calculate four indices (trade intensity, U.S.-CO_2 intensity, E.U.-CO_2 intensity, and energy intensity) because there are no provisions on the identification of EITE industries in Japan. Therefore, it is possible to test both the W.M. and the E.U.-ETS criteria.

Trade Intensity

Calculating trade intensity is relatively simple. Both W.M. and E.U.-ETS use import, export, and shipment or annual turnover. The figures for domestic production, export, and import listed in the I–O table are used to calculate the trade intensity index as

$$\text{Trade Intensity} = \frac{\text{Export} + \text{Import}}{\text{Domestic Production} + \text{Import}}$$

CO_2 Intensity

We are unaware of any published GHG emissions data for the Japanese industrial sector. Rather than estimating the GHG emissions by industry, we limit our scope of GHG intensity to reflect CO_2 emissions only. Thus, we refer to this index as CO_2 intensity. The language used in W.M. and the E.U.-ETS differs in that W.M. uses shipment, whereas the E.U.-ETS uses gross value added for the denominator. Thus, we calculate two separate CO_2 intensities to reflect the difference. Data for both domestic production and value added are collected from the I–O table.

The carbon price used is \14,667/t-C. Using this value, the consistency of the model in Section 2 and the indices are maintained. However, to compare the results with other studies, the carbon price can be adjusted.

The data used to estimate emissions from each sector are from the TVQ, which lists the quantity of purchased fossil fuel, electricity, and hot water/steam. We estimate the amount of fossil fuel combusted because the TVQ lists purchased fossil fuel rather than combusted fossil fuel. Therefore, we create combustion coefficients for each industry from *The Structural Survey of Energy Consumption in Commerce and Manufacturing* (METI). Finally, we use the emissions coefficient for each type of energy.

The sum, across industries, of the product of the quantity purchased, combustion coefficient, and emissions coefficient for each industry gives the total amount of emissions. However, this method is not appropriate for electricity for enterprise use, onsite power generation, and hot water/steam industries. If this method is applied to these three industries, the CO_2 emissions will be overestimated because these three industries are accounted for by indirect emissions of other industries. Thus, to avoid double counting, we adjust the direct emissions to zero for these three industries.

$$CO_2 \text{ Intensity}^{WM} = \frac{\text{Carbon Price} \times (\text{Direct Emissions} + \text{Indirect Emissions})}{\text{Domestic Production}}$$

$$CO_2 \text{ Intensity}^{EU} = \frac{\text{Carbon Price} \times (\text{Direct Emissions} + \text{Indirect Emissions})}{\text{Value Added}}$$

Energy Intensity

In W.M., energy intensity is unique; it is defined as

$$\text{Energy Intensity} = \frac{(\text{Fuel Cost} + \text{Indirect Enegy Cost})}{\text{Domestic Production}}$$

The original energy intensity uses electricity cost rather than energy cost. This formula is used to make energy intensity consistent with CO_2 intensity. In CO_2 intensity, indirect emissions are defined as emissions embodied within electricity and hot water/steam usage. The data for fuel cost and indirect energy cost is from the interindustry transaction table within the I–O table.

Appendix B. Decomposition of Cost Reduction

In this appendix, we briefly investigate the differences in the total cost reduction due to coverage differential by the E.U. and U.S. criteria.

Using the W.M. criteria, we identified 23 industries as EITE compared to 122 industries based on the E.U.-ETS criteria. The simulation results in this paper showed that the impact of the rebate program was similar for W.M. and the E.U., even though the total number of industries covered was very different. The difference between the two simulations originated from the coverage of the rebate program; direct and indirect emissions for the U.S. program and direct emissions only for the E.U. program.

We found 18 industries on both the E.U. and U.S. lists. Five industries—sugar; industrial soda chemicals; compressed gas and liquefied gas; pottery, china, and earthenware; and clay refractories—occur only on the U.S. list. The inclusion of energy intensity in the U.S. criteria resulted in this difference. Therefore, the U.S. list is not a subset of the E.U. list.

We recalculated the cost reduction for the five industries that are unique to the U.S. list, the 18 industries that are found on both lists using the W.M. rebate, the 18 industries that are found on both lists using the E.U. rebate, and the 104 industries that are found only on the E.U. list.

The average contribution of each group is shown in the first column of Table B1. In the U.S. simulation, 89 percent of the cost reduction is contributed by the 18 industries found on both lists, whereas the remaining 11 percent is contributed by the five U.S.-specific industries. In the E.U. simulation, the 18 industries contribute 75 percent of the reduction in total cost, whereas the remaining 25 percent is contributed by the 104 E.U.-specific industries. This result implies that the success of the rebate program is dependent on the 18 industries found on both lists. Therefore, if the Japanese government introduces an original criterion in determining EITE industries, these 18 industries will need to be included for the rebate program to be successful.

Table B1. Decomposition of Total Cost Reduction by Group

Composition		Reduction Rate		
		Average	Minimum	Maximum
Only found in WM Criterion	5 Industries	10.862%	0.099%	96.587%
Both found in WM and EU (WM Rebate)	18 Industries	89.138%	3.413%	99.901%
Both found in WM and EU (EU Rebate)	18 Industries	74.877%	13.922%	99.928%
Only found in EU Criterion	104 Industries	25.123%	0.072%	86.078%