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Analysis using a Disaggregated Input-Output Table"

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"Economic Impacts and Emissions Reduction Effects of JCM: Analysis using a Disaggregated Input-Output Table[1]"

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Abstract

Emissions reductions in developing countries are essential for achieving the targeted atmospheric CO_2 concentration of 450 ppm. Although the Clean Development Mechanism (CDM) has been effective in reducing emissions in developing countries, this mechanism has also been criticized by various parties (Arimura et al., 2012). In response to this criticism, new mechanisms providing solutions to these problems have evolved in Europe and Japan: the EU has proposed the Sectoral Crediting Mechanism (SCM) as a new method for international offsets, and the Japanese government has advocated the Joint Crediting Mechanism (JCM).

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The proposed JCM is similar to the CDM but differs in its specifics. For instance, the type of projects suitable under the JCM will be determined by a joint committee between Japan and the host country. In addition, the JCM may be applied to electrical appliances and infrastructure projects.

The Ministry of the Environment (MOE) and the Ministry of the Economy, Trade and Industry (METI) have conducted feasibility studies (FSs) on this issue since 2010. These studies have focused on identifying technological needs, monitoring, reporting and verification (MRV) methods, and capacity building but have not investigated the economic impacts and the reduction possibilities that the JCM may generate.

We estimated the economic impacts, employment effects, and emissions reductions anticipated with implementation of the JCM. We relied on the 2010 Japanese domestic input-output table as our base dataset. One of the difficulties in our JCM evaluation involved the inclusion of specific energy-efficient appliances, trains, or products such as hybrid vehicles and solar panels. In a typical input-output table, these products are not treated as independent sectors. To overcome this challenge, we created specific sectors of hybrid vehicles and solar panels by disaggregating the standard input-output table. We used the disaggregated input-output table to estimate the economic impacts of the JCM. Then, we estimated the annual and total emissions reductions under the JCM using country-specific emissions coefficients for eleven different countries.

We assumed that the JCM will increase Japanese exports by ¥10 billion for nine technologies/products: hybrid vehicles, solar panels, trains, coke dry quenching (CDQs), boilers, light-emitting diode (LED) light bulbs, batteries, air conditioners, and refrigerators/washing machines. We also assumed a ¥10 billion increase in exports originating from Vietnam, Thailand, Philippines, Indonesia, India, Bangladesh, Mongolia, Sri Lanka, Mexico, Colombia, and Malaysia.

We found that the economic impacts of hybrid vehicles and air conditioners were high, whereas boilers and light bulbs produced smaller effects. The results for the employment effects showed that the CDQ and refrigerator/washing machine industries created the most jobs of all nine technologies/products.

The results from the emissions reduction analysis showed that washing machines have the highest per annum emissions reduction. In contrast, LEDs and refrigerators have small per annum emissions reductions. The total emissions reduction calculated according to the lifetime of the technology/product yielded the highest reductions for CDQs, followed by washing machines.

These results suggest that it is important to balance expected economic and emissions reduction effects when determining which technologies/products to invest in. Therefore, the Japanese government must assess various technologies/products before determining which should be eligible for JCM projects.

JEL classification: Q54, Q56, C67

1. Introduction

Emissions reductions from developing countries are essential for achieving the targeted atmospheric carbon dioxide (CO_2) concentration of 450 ppm. The first phase of the Kyoto Protocol (KP) did not include a mandatory target for developing countries. However, the Clean Development Mechanism (CDM) was included in the KP and has promoted reductions in CO_2 emissions from developing countries.

Recent negotiations regarding an international agreement that includes targets for major CO_2 emitters have not been successful. As a result, the KP has been extended until an international agreement materializes. The extension of the KP does not imply that revisions of market mechanisms, such as the CDM, are unnecessary. In fact, the CDM has been criticized by various parties, and possible revisions have been discussed.

To provide a long-term solution for regulating CO_2 emissions, an international framework that includes mitigation strategies for every country is critical. However, a short-term solution would include bilateral and multilateral arrangements to encourage emissions reductions in developing countries. The CDM has been successful in reducing emissions, but these approved projects have been implemented only in very limited parts of the world. The international community has proposed new mechanisms that could increase the number of projects and countries striving toward reduced emissions.

One example of such a new mechanism is the Sectoral Crediting Mechanism (SCM) proposed by the European Union (EU) (Bolscher et al., 2012). In the SCM, emissions reduction is conducted at the sector level instead of the project level. The EU is considering applying this mechanism to energy-intensive sectors such as the iron and steel, electric power, and cement industries. For this mechanism to be successful, each developing country must have its own emissions reduction target for the sectors covered by the SCM; this is a difficult criterion for many developing countries to accept at this stage. The negotiations at the United Nations Climate Change Conference (UNFCCC) included the possibility of developing new mechanisms for the post-Kyoto period. However, decisions were not finalized, and additional discussions will be held for the SCM under "new mechanisms."

Another example of a new mechanism proposed by the international community is the Joint Crediting Mechanism (JCM). The Japanese government has searched for various ways to contribute to reductions in global CO_2 emissions, especially emissions from developing countries. The current situation surrounding climate change policy in Japan has promoted the JCM. For example, the recent earthquake in the Tohoku region and the resulting nuclear accident have made the Japanese government reluctant to support the extended KP. As a result, Japan will be unable to trade CDM credits, but it is willing to reduce domestic and international emissions.

The JCM has been proposed as one of the "various approaches" at the previous UNFCCC meetings. However, no quantitative economic analyses have been conducted. If the JCM is to be recognized by the international community, a thorough economic assessment will be necessary. In the present study, we focused on the potential economic and employment effects of the JCM. We also examined whether the emissions reduction would be greater than the additional emissions caused by offsetting economic activities.

We applied an input-output analysis to evaluate the economic impacts of the JCM; this analysis allowed us to calculate the demands of the intermediate goods of the product/technology chosen for the JCM. One of the difficulties in our JCM evaluation involved the inclusion of specific energy-efficient appliances, trains, or products such as hybrid vehicles and solar panels. In a typical input-output table, these products are not treated as independent sectors. To overcome this challenge, we created specific sectors of hybrid vehicles and solar panels by disaggregating a standard input-output table. This approach is our methodological contribution to the literature of environmental economics and I-O analysis.

The paper is organized as follows: Section 2 briefly introduces the proposed JCM and its evolution; Section 3 provides a description of the model used to estimate economic, employment, and additional emissions variables and the methods used to calculate emissions reductions; Section 4 presents results; and Section 5 concludes.

2. Joint Crediting Mechanism (JCM)

2.1. Design and Goals of the JCM

In September 2009, the Japanese government announced that the mid-term goal for the year 2020 was a 25% reduction in CO_2 emissions from 1990 levels. Japan planned to meet this goal by reducing domestic emissions with the use of offset credits from abroad. More precisely, the Japanese government planned to reduce global emissions, especially in developing countries. One idea was to export energy-efficient products/technologies of Japanese firms.

During this same time period, the Japanese government sought new mechanisms other than the CDM to assist Japanese firms in reducing global greenhouse gas (GHG) emissions because the firms were unsatisfied with the current CDM due to the time-consuming process of issuing the certified emissions reductions (CERs), the additional requirements that must be met for CERs to be issued, the volume of CERs issued, and the regional imbalance of CDM projects (Arimura et al., 2012).

In addition, Japanese firms criticized the type of projects eligible for CDM. For example, nuclear power plants and energy-efficient appliances were not included in the CDM. Thus, Japanese firms pressured the government to develop a new mechanism.

As a result, the Japanese government proposed the JCM, which aims to address the main issues expressed by the firms and to extend the scope of activities eligible for inclusion in emissions-reduction programs. The proposed elements of the JCM are as follows:

"1) To facilitate diffusion of leading low carbon technologies, products, systems, services, and infrastructure as well as implementation of mitigation actions, and contributing to sustainable development of developing countries, 2) to appropriately evaluate contributions to GHG emission reductions or removals from developed countries in a quantitative manner, through mitigation actions implemented in developing countries and use those emission reductions or removals to achieve emission reduction targets of the developed countries and 3) to contribute to the ultimate objective of the UNFCCC by facilitating global actions for emission reductions or removals" (New Mechanisms Information Platform website[6]).

Table 1 summarizes the differences between the proposed JCM and the CDM. The governance of the JCM will be enforced via a bilateral committee between Japan and the host country. In contrast, the CDM executive board is set multilaterally under the United Nations.

The bilateral committee established between Japan and the host country will decide which product/technology will be eligible for the JCM. The committee will construct a list including the possible products/technologies with the amount of reduction (credits) each product/technology will achieve.

Table 1. Comparison between JCM and CDM

	JCM	CDM
Governance	Decentralized Structure: Bilateral Committee	Centralized Structure: Executive Board
Scope of Activities	From Projects to Markets	Project Based
Verification	Positive List or Benchmarking	Additionality Approach
Investors	Japanese Government Private Firms	Governments Private Firms
Tradability of Credits	Non-tradable Tradable	Tradable

The Japanese government will finance the projects/activities in the early stages of the JCM. As the JCM matures, private firms are expected to finance projects without assistance from the government. The determination of Keidanren's Voluntary Action Plan for the post-Kyoto period may also influence the participation of private firms in the JCM. It should be noted that credits obtained via the JCM will not be tradable at least in the early stages.

[6] The New Mechanisms Information Platform website provides detailed information on the JCM (http://www.mmechanisms.org/e/initiatives/index.html, accessed Jan 7, 2013).

Another unique feature of the JCM is the fact that participants include only firms based in Japan. Firms that are not located in Japan cannot participate in the early stages of the program. This requirement does not imply that the technology/product must be manufactured in Japan but, rather, that if there are restrictions on the origin of manufacturing, then the JCM will not comply with GATT/WTO regulations because at least in the early stages, JCM is financed by the Japanese government and may take a form of subsidies. It should be noted that these proposed structures of JCM will be subject to changes as the negotiation under UNFCCC evolves.

2.2. Recent Advances of the JCM

The Ministry of the Environment (MOE) and the Ministry of Economy, Trade and Industry (METI) have been engaged in feasibility studies (FSs) since 2010. One objective of the FSs is to gather information on environmental technological needs from potential host countries. The FSs will likely be used as a basis for discussions regarding the construction of the list of eligible products/technologies when the bilateral committee is established.

Projects included in the FSs include the installation of energy-efficient boilers, building energy management systems (BEMS), mass rapid transits (MRT), and waste management and power plants. Therefore, a variety of activities are presumably eligible for the JCM.

The FSs have been conducted in various parts of the world. For instance, BRICS have been host countries for the FSs. Small island countries such as Maldives and African countries such as Djibouti are also included in the FSs. Thus, the Japanese government hopes to include developing countries that did not host many CDM projects.

The Japanese government has advocated the JCM since 2009 in hopes of expanding the list of possible host countries. To date, the Japanese government has signed JCM bilateral documents with Mongolia (January 2013), Bangladesh (March 2013), Ethiopia (May 2013), Kenya (June 2013), Maldives (June 2013), Vietnam (July 2013), Laos (August 2013), Indonesia (August 2013), Costa Rica (December 2013), and Palau (January 2014). These countries are currently working with the Japanese government to establish the bilateral committees.

The JCM has received support from the Japanese private sector. A survey conducted by the Keidanren found that Japanese firms are interested in the JCM because the new mechanism will allow these firms to assist developing countries in reducing their emissions (Japan Keidanren, 2013).

3. Model and Data

3.1. Model

If the JCM is implemented, the mechanism will generate new demand for energy-efficient products/technologies in developing countries and, thus, increase exports from Japan. This increase in exports will directly increase the economic activity of industries producing the products/technologies. In addition, the new demand will indirectly increase the economic activity of industries that supply intermediate goods to the production industries. We used the input-output model because it captures the direct and indirect effects of the increased volume of exports.

Assuming the economy consists of n sectors, the total output for each sector is the sum of the intermediate output, domestic final demand, and exports minus the imports, or

$$X = AX + F^d + E - M \qquad (1)$$

where X is the vector of total output, A is the matrix of input coefficients, F^d is the vector of domestic final demand, E is the vector of exports, and M is the vector of imports. Equation (1) assumes that imports are exogenous to domestic economic activity. However, it is more realistic to assume that imports change with domestic economic activity. Thus, we must treat imports as endogenous, or

$$X = \left(I - \hat{M}\right)AX + \left(I - \hat{M}\right)F^d + E \qquad (2)$$

where $\hat{M}$ is an n by n square matrix with the diagonal component of $\frac{m_i}{X_i}$, or the import ratio, and all other components of zero, and I is the usual n by n entity matrix. Solving equation (2) for X yields

$$X = \left(I - (I - M)A\right)^{-1}\left((I - M)F^d + E\right) \qquad (3).$$

The $\left(I - (I - M)A\right)^{-1}$ is the Leontief inverse matrix, which shows the direct and indirect input requirements used to produce one unit of output.

The JCM is assumed to change the export vector. If we denote the change in the final demand as ΔE, then we can calculate the effect of the JCM on the entire Japanese economy as follows:

$$\Delta X = \left(I - (I - M)A\right)^{-1}\Delta E \qquad (4).$$

Equation (4) allows us to calculate the direct and indirect effects of the increase in exports that are financed exogenously. Thus, the increase in value added will equal the increase in exports.

However, because equation (4) treats imports as endogenous, the total value added within Japan will not equal the increase in exports. In other words, the increase in exports of good A will increase the imports of raw materials and intermediate goods to satisfy the additional demand for good A. Therefore, we can calculate the additional "domestic" value added by using the following equation:

$$\Delta VA = V\Delta X \tag{5}$$

where ΔVA is the change in value added (vector) and V is an n by n square matrix with the value-added-to-sales ratio as the diagonal elements and zero as the non-diagonal elements.

We can also calculate the effect of the JCM on employment using the following equation:

$$\Delta L = l\Delta X \tag{6}$$

where l denotes the employment coefficient vector and ΔL denotes the change in labor (vector). Each argument in the employment coefficient is calculated by dividing the number of employees in industry i by the total output of industry i.

3.2. Data

The "basic classification" of the 2010 Japanese domestic input-output table consists of 520 products (rows) produced by 407 industries (columns). The number of rows must equal the number of columns to calculate the inverse matrix (Leontief inverse matrix) presented in the previous section. Since there are some industries that produce the same product, for example electricity, the 401 industrial classifications[7] are the finest-scale industrial classifications for the Japanese economy.

The objective of the JCM is to export environmental technologies or energy-efficient products to developing countries. Therefore, it is important to distinguish between highly energy-efficient products/technologies and "average" products/technologies. The I-O table, however, does not distinguish environmentally friendly products from ordinary products. Therefore, the original Japanese I-O table does not allow us to analyze the effect of the JCM in depth. However, it is important to analyze the effect of the JCM using more detailed industries.

We increased the accuracy of the analysis by disaggregating relevant industries into highly efficient products and average products. The hybrid automobile industry and the solar panel industry

[7] The Stone method is used to construct the Japanese I-O table. The original table includes two scrap industries: the iron scrap industry and the non-ferrous metal scrap industry. Treating the two scrap industries as independent industries results in a 403 by 403 square matrix. However, we do not treat the two industries independently. The figures for the iron scrap industry are added to those of the iron and steel industry. Similarly, we add the figures for the non-ferrous metal scrap industry to those of the non-ferrous metal industry. As a result, our data set is a 401 by 401 square matrix before the disaggregation process.

were added to the I-O table (the details are shown in the appendices). We used data provided by the Japanese Automobile Manufacturing Association (JAMA) and the Institute for Energy Economics (2006) to disaggregate the original 401 by 401 I-O table to construct a 402 by 402 I-O table. We also used data from the "Handbook of energy and economic statistics in Japan" (EDMC, 2013), data provided by Japan Photovoltaic Energy Association (JPEA) and Optoelectronics Industry, and data from the Technology Development Association (OITDA) to create a 403 by 403 I-O table.

3.3. Calculating Emissions Reductions

The emissions reductions resulting from the implementation of JCM is calculated in several ways. Regarding the energy efficient electricity appliances, the emission reduction $\Delta CO2_{ik}^{host}$ for product k in country i, is calculated by

$$\Delta CO2_{ik}^{host} = Q_i \times e_i^{electricity} \times \Delta\theta_k = Q_i \times e_i^{electricity} \times \left(\theta_k \times \Delta efficiency\right) \qquad (7)$$

where Q_i denotes the quantity of energy-efficient products that are exported under the JCM, $e_i^{electricity}$ denotes the CO_2 emissions intensity of electricity in country i, $\Delta efficiency$ is the change in energy efficiency, and θ_k is the annual energy consumption of product k in kWh.

The CO_2 emissions intensity of electricity was collected from SunEarthTools[8]. The CO_2 emissions per kWh are shown in Table 2 Mongolia has the highest CO_2 emissions intensity, at 1.49 kg/kWh, followed by India's 0.95 kg/kWh because of these countries' heavy reliance on coal. The CO_2 emissions intensity is the lowest for Colombia. Along with Sri Lanka and Vietnam, Colombia has a lower emissions intensity than Japan which may be the result of the high ratio of hydropower in the grid in these three low-intensity countries.

We were unable to collect data on the energy efficiency of appliances in the host countries. Therefore, we assumed that the energy efficiency of appliances in the host countries is 30% lower than the products that would be exported by the JCM. In other words, the energy efficiency would improve by 30% with the implementation of the JCM. Furthermore, if we assume that there is no rebound effect, then the amount of electricity consumed by the electrical appliances will decrease by 30%.

[8] http://www.sunearthtools.com/tools/CO2-emissions-calculator.php

Table 2. CO_2 Emissions Intensity of Electricity

Country	CO_2 Emissions Intensity (kg-CO_2/kWh)
Bangladesh	0.59
Colombia	0.18
India	0.95
Indonesia	0.75
Malaysia	0.73
Mexico	0.45
Mongolia	1.49
Philippines	0.48
Sri Lanka	0.38
Thailand	0.51
Vietnam	0.38
Japan	0.42

We must also make an assumption concerning the price of the exported product. This point is crucial when estimating the emissions reductions because if we use a price that is too low, the volume of trade will be large, leading to an overestimation of emissions reductions. In contrast, if the price is too high, then the volume of trade will be small, which leads to an underestimation of emissions reductions.

Two possible figures can be used as the price of the product: the Japanese domestic price and the host country price. Because energy-efficient products have higher market prices, the Japanese domestic price can be considered as the upper limit; thus, we assumed that the price of the goods is the Japanese domestic price.

Another crucial factor in estimating emissions reductions is the time span considered. If we assume that new technology will not be implemented in the future, then the emissions reduction from Japanese exports will be very large. However, if we assume that new technology will diffuse immediately, then the emissions reduction from Japanese exports will be very small. We assumed that the emissions reduction will be calculated by multiplying the life expectancy[9] of the product by the annual emissions reduction. In other words, we assumed that the "business as usual" case only applies to old appliances.

For other types of products and technology, we used the following methods to calculate the emission reductions. To estimate the GHG reduction from the promotion of hybrid vehicles, we must identify the annual gasoline consumption per vehicle in each country. We used the information from

[9] The life expectancies of products are assumed vary: hybrid vehicles, 12.2 years; solar panels, 17.0 years; industrial furnaces, 20.0 years; lighting equipment, 15.0 years; air conditioners 10.7 years; washing machines, 9.8 years; and refrigerators, 10.7 years.

the World Bank[10] for this estimation. We assumed that hybrid vehicles are 55% more efficient than vehicles currently used in each country. For the emission reduction from the promotion of the solar panel, we incorporated the differences in daylight hours across countries[11]. For the emission reduction from CDQ, we used the information from the feasibility study[12].

3.4. Simulation Scenarios

At the present stage, it is difficult to estimate the new investment that the JCM will stimulate. Therefore, we must assume a value that is fairly reasonable. In this present study, we assumed that the amount of new investment will be ¥10 billion[13].

Table 3. Simulation Scenario

	Increase in Exports
Hybrid Vehicles	¥10 billion
Solar Panels	¥10 billion
Trains	¥10 billion
Boilers	¥10 billion
Industrial Furnaces	¥10 billion
Lighting Equipment	¥10 billion
Batteries	¥10 billion
Air Conditioners	¥10 billion
Refrigerators/Washing Machines	¥10 billion

First, we considered the following nine products/technologies in the I-O analysis as potential candidates for the JCM because they have been studied in the FSs or discussed as possible candidates: hybrid vehicles, solar panels, trains, boilers, industrial furnaces, lighting equipment, batteries, air conditioners, and refrigerators/washing machines[14] (Table 3).

We also assumed that the product/technology will be manufactured in Japan. This assumption was applied because only those firms based in Japan will be eligible to participate in the projects in the early stages of the JCM. In other words, the exports from Japan will increase by a

10 http://data.worldbank.org/indicator/IS.ROD.SGAS.PC/countries?display=default
11 http://www.climatemps.com/
12 http://gec.jp/main.nsf/jp/Activities-GHGmitimecha-FS2011newmex17
13 This is a hypothetical figure without any supporting evidence.
14 The refrigerator and washing machine industries are not distinguished in the Japanese I-O table. Therefore, we cannot calculate the economic effect and employment effect for each product in the I-O analysis without disaggregating the data, which is outside the scope of this study.

magnitude of ¥10 billion.

Next, we considered the following seven products/technologies in the calculation of emissions reductions: hybrid vehicles, solar panels, trains, industrial furnaces, lighting equipment, refrigerators, and washing machines.[15] We focused on these seven of the potential 10 products/technologies due to data availability. The volume of emissions reductions achieved by the energy-efficient technology will vary across countries. Thus, we considered the following eleven potential host countries for the JCM: Bangladesh, Colombia, India, Indonesia, Malaysia, Mexico, Mongolia, Philippines, Sri Lanka, Thailand, and Vietnam.

4. Results

4.1. Results from the I-O Model

The results of the simulation are shown in Table 4. The economic effects of an increase in exports of ¥10 billion ranged from ¥18.49 billion to ¥33.75 billion. The difference in the magnitude of the economic effects was due to the difference in the relationships of the industries. The hybrid vehicle industry had the greatest economic effect, at ¥33.75 billion. In contrast, the solar panel industry had the smallest economic effect, at only ¥18.49 billion.

The results of the employment effect show a different story. The lighting equipment industry had the highest employment effect, followed by the industrial furnace industry and the hybrid vehicle industry. Once again, the solar panel industry had the smallest employment effect. Other industries with relatively small employment effects were the air conditioner, boiler, and battery industries.

As for the increase in domestic value added, the boiler industry had the highest increase, whereas the solar panel industry had the smallest increase. However, the magnitude of the differences between the highest and lowest industry was not as large as the difference in economic effects.

These results from the I-O analysis indicate that balancing economic, value-added, and employment effects is necessary when choosing the type of program suitable for the JCM to efficiently allocate resources. If the JCM intends to increase economic activity, then choosing hybrid vehicles, trains, and air conditioners are suitable goods. However, if the JCM intends to increase labor, then lighting equipment, industrial furnaces, and hybrid vehicles are better choices.

[15] The average consumption of electricity is essential in estimating emissions reductions. Because there are a variety of products, we selected four distinct products/technologies to be used in the analysis. We assumed that CDQ systems will be exported under industrial furnaces, the ZABOON AW-90DL (Toshiba) will be the typical washing machine exported, the NR-F507XV (Panasonic) will be the exported refrigerator, and the MILIE LDA10D-G-D1 (Mitsubishi Electric) will be the typical lighting equipment (LED) exported.

Table 4. Economic Impacts of JCM with ¥10 billion export

	Economic Effect (Billion ¥)	Employment Effect	Value Added (Billion ¥)
Hybrid Vehicles	33.75	980	8.31
Average Vehicles	30.74	874	8.30
Solar Panels	18.49	586	7.46
Trains	24.45	954	8.30
Boilers	20.36	785	8.99
Industrial Furnaces	22.44	988	8.68
Lighting Equipment	21.99	992	8.39
Batteries	22.03	788	7.74
Air Conditioners	23.23	721	7.95
Refrigerators Washing Machines	22.28	914	7.94

Note A: We include the "Average Vehicles" industry as a reference.

The additional CO_2 emissions due to increased demand (production) were also calculated. They were estimated to be between 21,968 t-CO_2 and 49,488 t-CO_2. Air conditioners showed the smallest increase in CO_2 whereas the production of trains would emit the most during production.

4.2. Emissions Reductions Achieved by the JCM

The I-O analysis provides valuable information on the economic and employment effects of the JCM. The ultimate goal of the JCM, however, is the reduction of CO_2 emissions in developing countries. Based on economics, projects should be determined by cost-efficiency standards. Thus, the calculation of potential emissions reductions is necessary.

Table 5 shows the estimated emissions reductions resulting from the implementation of the JCM. The emissions reductions achieved by products differ greatly. In general, the per annum emissions reduction is the highest for lighting equipment, followed by air conditioners. In contrast, washing machines will reduce emissions the least per annum.

Table 5 also shows the emissions reduction differences among countries. For example, the emissions reduced for hybrid vehicles in Vietnam are higher than in other countries. With regard to solar panels, the emissions reduction is the greatest for India and the smallest for Colombia.

Table 5. Estimated Emissions Reductions (t-CO_2/year)

	Hybrid Vehicle	Solar Panel	Coke Dry Quenching	Lighting Equipment	Air Conditioner	Washing Machine	Refrigerator
Vietnam	20,944	10,354	-	47,410	45,365	534	5,227
Thailand	2,601	-	-	56,337	53,907	635	6,212
Philippines	5,264	20,842	-	52,835	50,556	595	5,826
Indonesia	7,120	43,460	-	77,887	74,528	878	8,588
India	3,468	54,423	21,342	101,486	97,109	1,144	11,190
Bangladesh	4,448	-	-	65,095	62,287	734	7,177
Mongolia	7,887	-	-	163,841	156,774	1,846	18,065
Sri Lanka	3,333	-	-	41,621	39,825	469	4,589
Mexico	5,591	24,336	-	49,961	47,806	563	5,509
Colombia	4,567	6,180	-	19,304	18,471	218	2,128
Malaysia	4,779	33,436	-	79,897	76,451	900	8,809

Table 6 shows the estimated emissions reductions during the lifetime of the product. The expected lifetime of products ranges from 9.8 to 20 years. The difference in the estimated emissions reduction after considering the life expectancy of the product is larger. The results show that lighting equipment and air conditioners have higher emissions reductions than other products.

Table 6. Estimated Lifetime Emissions Reductions (t-CO_2)

	Hybrid Vehicle	Solar Panel	Coke Dry Quenching	Lighting Equipment	Air Conditioner	Washing Machine	Refrigerator
Vietnam	254,680	176,017	-	711,153	485,408	5,236	55,933
Thailand	31,622	-	-	845,057	576,807	6,222	66,465
Philippines	64,006	354,314	-	792,520	540,947	5,835	62,333
Indonesia	86,580	738,817	-	1,168,310	797,448	8,602	91,890
India	42,165	925,186	426,830	1,522,289	1,039,061	11,208	119,731
Bangladesh	54,086	-	-	976,420	666,470	7,189	76,797
Mongolia	95,907	-	-	2,457,618	1,677,484	18,094	193,296
Sri Lanka	40,534	-	-	624,308	426,131	4,596	49,103
Mexico	67,984	413,704	-	749,413	511,523	5,518	58,943
Colombia	55,530	105,062	-	289,553	197,639	2,132	22,774
Malaysia	58,110	568,413	-	1,198,460	818,027	8,824	94,261

Caution is needed when interpreting the results. The emissions reductions shown in Table 6 can be considered the maximum or upper bound of emissions reductions because we did not discount the value of future emissions reductions. Furthermore, the actual emissions reductions achieved by the additional exports will depend on the guidelines set forth by the JCM joint committee. If a bilateral committee decides to verify emissions reductions for the initial year of the project, the emissions reduction will be very small. In contrast, if the committee decides to verify emissions reduction for the entire lifetime of the product without a discount rate, then the emissions reduction will be very large.

4.3. Cost Effectiveness of JCM

The previous two subsections estimated the economic impacts, labor impacts, and emissions reductions based on the implementation of the JCM with a magnitude of ¥10 billion. We estimated the cost (government expenditure) per ton of emissions reduction using the results from the previous subsection. This estimated cost does not correspond to the marginal abatement cost; however, it provides information that the government can use to decide which type of projects to choose among numerous options. In addition, this estimated cost can be used to compare the efficiency of the JCM to that of other programs that the government has implemented.

Table 7. Cost (Government Expenditure) per Ton of Emissions Reduction (¥/t-CO_2)

	Coke Dry Quenching	Washing Machine	Refrigerator	Lighting Equipment	Hybrid Vehicle	Air Conditioner	Solar Panel
Vietnam	-	636,641	59,595	4,687	13,088	6,867	18,938
Thailand	-	535,762	50,151	3,945	105,411	5,779	-
Philippines	-	571,278	53,476	4,206	52,079	6,162	9,408
Indonesia	-	387,525	36,275	2,853	38,500	4,180	4,512
India	15,333	297,413	27,840	2,190	79,055	3,208	3,603
Bangladesh	-	463,683	43,404	3,414	61,630	5,001	-
Mongolia	-	184,223	17,245	1,356	34,756	1,987	-
Sri Lanka	-	725,202	67,885	5,339	82,235	7,822	-
Mexico	-	604,138	56,552	4,448	49,031	6,516	8,057
Colombia	-	1,563,615	146,367	11,512	60,027	16,866	31,727
Malaysia	-	377,776	35,363	2,781	57,363	4,075	5,864

We assume that the Japanese government will provide one-third of the funding needed to conduct projects: for a ¥10 billion JCM project. In other words, it is assumed that ¥3.33 billion will be financed by the government.

Table 7 shows the per ton cost funded by the government. The results indicate that cost effectiveness differs among products. In general, the cost effectiveness of lighting equipment was the highest, followed by air conditioners and solar panels. In contrast, washing machines, refrigerators, and hybrid vehicles had relatively low cost effectiveness.

Table 7 also shows that the cost effectiveness differs among countries. For example, the cost effectiveness for Mongolia and India are high, whereas the cost effectiveness for Colombia and Vietnam are low.

5. Conclusion

In this study, we analyzed the effects of the JCM using the I-O model and calculated emissions reductions resulting from the export of energy-efficient products/technologies. We assumed that the JCM will increase Japanese exports by ¥10 billion for nine products and then focused on seven products and calculated the potential CO_2 emissions reduction for each.

The results from the I-O model showed that there is a tradeoff between the effects of economic activity and employment. For example, the hybrid vehicles had the highest economic impact, followed by trains, air conditioners, and industrial furnaces. In contrast, lighting equipment had the highest labor impact, followed by industrial furnaces, hybrid vehicles, and trains. Therefore, a balance of economic activity and employment is needed when considering which products should be included in the JCM.

The emissions reductions calculated for the seven products showed that the volume of emissions reduction differs among regions and products. Therefore, the JCM will only create credits for limited products and countries. In summary, the results suggest that the JCM must be carefully designed to achieve net emission reductions and generate economic benefits.

From a policy perspective, the results showed that lighting equipment and air conditioners can deliver emissions reductions with relatively low costs, whereas washing machines, refrigerators, and hybrid vehicles have relatively high costs. It is important to note that these results do not imply that products/technologies that are cost inefficient should not be exported, as one purpose of the JCM is to contribute to sustainable development in the host country.

The four main points concerning the analysis in this study and the future of the JCM are summarized below.

1) The finance of the new exports is uncertain in our framework. If the JCM is financed by the government using tax revenues, then the tax must be incorporated in the analysis. However, if Japanese firms finance the projects, the model must account for that scenario.

2) The emissions reductions calculated in this study rely on strong assumptions. For example, the exported products are expected to increase energy efficiency of electric appliances by 30%. The products that are replaced may have higher energy efficiency than expected. Therefore, the emissions reductions could be lower than our estimates. In addition, we assumed that products will be replaced rather than newly installed. If the products are not used in the average household of the host country, then the emissions will increase as a result of the JCM.

3) The JCM must be WTO compliant. The WTO prohibits export subsidies, but for our analysis, we

assumed that the Japanese government will provide export subsidies to domestic producers. Thus, the JCM must be designed so that the funding from the government does not become an export subsidy.

4) Our analysis focused on CO_2 emissions and the economic effects from the production of the products. Development of the host country is an important component of the JCM. Our analysis overlooked other economic and environmental benefits. Therefore, further analyses are needed using other criteria before making a final decision about which products will be appropriate for inclusion in the JCM.

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Appendix A Disaggregating the Input-Output Table

1. Disaggregating the automobile industry

The automobile industry produces gasoline, diesel, and hybrid vehicles.[16] However, the Japanese I-O table does not distinguish among these types of vehicles even in the most disaggregated industrial classification, which is the passenger motor vehicle industry. Thus, the passenger motor vehicle industry must be disaggregated to calculate the effects of exporting hybrid vehicles specifically. In this section, we describe the method used to disaggregate the passenger motor vehicle industry.

1.1 Disaggregation of the column

The value of shipment, value-added ratio, and input ratio are needed to disaggregate the column of the I-O table. Because the value-added ratio and input ratio are confidential, we estimated these figures using the steps described below.

The first step in disaggregating the column of the I-O table was to calculate the total shipment[17] for the average vehicle and hybrid vehicle to be used as the final factor for both the column and row of each industry. We estimated the average price of a hybrid vehicle and average vehicle to estimate the total shipment. The average price of a vehicle calculated from the original I-O table can be written as follows:

$$P_{AUTO} = \frac{Y_{AUTO}}{Q_{AUTO}} = \frac{Y_{AUTO}}{Q_{AVE} + Q_{HYBRID}} \qquad \text{(A-1)}$$

where Y_{AUTO} is the value of shipment reported in the I-O table and Q_{AUTO} is the quantity of shipped vehicles. We can simplify Q_{AUTO} into two terms: the quantity of shipped average vehicles, Q_{AVE}, and the quantity of shipped hybrid vehicles, Q_{HYBRID}. The number of average vehicles is reported by the Japan Automobile Manufacturers Association (2012); the number of hybrid vehicles is provided by JAMA's homepage.[18] Using this equation (A-1), the average vehicle price was calculated as ¥1.69 million.[19]

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[16] Hereafter, we will refer to gasoline, diesel, and other non-hybrid vehicles as "average" vehicles.

[17] Total shipment refers to the domestic production, the sum of inputs and value added, in the I-O table.

[18] The number of hybrid vehicles shipped in 2010 can be obtained via JAMA's homepage at http://www.jama-english.jp/statistics/eco_friendly/2010/111111_ref.html.

[19] The shipment from the passenger motor vehicle industry was ¥14.07 trillion according to the 2010

The average price calculated above includes non-hybrid vehicles. Therefore, we could not use this price to disaggregate the I-O table. To overcome this problem, we collected additional price data for the average gasoline vehicle and hybrid vehicle. According to Takeda (2012), the average price of a hybrid vehicle[20] is ¥2.2 million (US$22,000), and the average price of a gasoline vehicle with similar characteristics is ¥1.8 million (US$18,000). Thus, the price difference is approximately ¥0.4 million. We used this information to calculate the average price of an average vehicle and that of a hybrid vehicle.

The total shipment for the passenger motor vehicle industry is the sum of average vehicle shipment, Y_{AVE}, and hybrid vehicle shipment, Y_{HYBRID}, or

$$Y_{AUTO} = Y_{AVE} + Y_{HYBRID} \qquad \text{(A-2).}$$

The relationship between shipment and price for both vehicles is

$$\begin{aligned} Y_{AVE} &\equiv P_{AVE} \times Q_{AVE} \\ Y_{HYBRID} &\equiv P_{HYBRID} \times Q_{HYBRID} \end{aligned} \qquad \text{(A-3).}$$

Furthermore, the relationship between the price of the hybrid vehicle, P_{HYBRID}, and the average vehicle, P_{AVE}, is

$$P_{HYBRID} = P_{AVE} + 400{,}000 \qquad \text{(A-4).}$$

Combining equations (A-3) and (A-4) with equation (A-2) gives the average price of an average vehicle as

$$P_{AVE} = \frac{Y_{AUTO} - (400{,}000 \times Q_{HYBRID})}{(Q_{AVE} + Q_{HYBRID})} \qquad \text{(A-5).}$$

Using this value, we calculated the average price of a hybrid vehicle. The average price of an average vehicle was calculated to be ¥1.67 million, whereas the price for a hybrid vehicle was ¥2.07

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domestic I-O table, and the number of vehicles shipped was 8.31 million (Japan Automobile Manufacturers Association, 2012).

[20] Takeda (2012) assumes that Toyota's Prius is the average hybrid vehicle.

million.[21] Using these two figures, we calculated the total shipment for average vehicles and hybrid vehicles using equation (A-3), which is ¥13.06 trillion for average vehicles and ¥1.01 trillion for hybrid vehicles.

The second step was to disaggregate the value of input from each industry to the hybrid vehicle and average vehicle industry. We needed cost information, which is usually confidential information, to disaggregate the passenger vehicle industry into two industries. We relied on the fact that the price difference arises from four sources: engine/generator, power control unit, batteries, and other parts for hybrid vehicles (Takeda, 2012). Furthermore, Takeda (2012) showed that the engine/generator, power control unit, and other parts for hybrid vehicles each account for ¥0.08 million, whereas batteries account for ¥0.16 million.

Furthermore, Takeda (2012) assumed that the batteries are supplied to the hybrid vehicle industry by the battery industry, the engine/generator is supplied by the rotating electrical equipment industry, and the power control unit and other parts are supplied by other electrical devices and parts industry. These assumptions are valid if the input values from these industries are not zero in the original I-O table. This is not the case, however, for the engine/generator, power control unit, and other parts industries. Thus, we assumed that the engine/generator, power control unit, and other parts for hybrid vehicles are supplied by the motor vehicle parts and accessories industry.

We used the following equations to disaggregate the input values with the exception of the batteries and motor vehicle parts and accessories industries:

$$X_{i,AVE} = X_i \frac{Q_{AVE}}{Q_{AUTO}} \qquad \text{(A-6),}$$

$$X_{i,HYBRID} = X_i \frac{Q_{HYBRID}}{Q_{AUTO}} \qquad \text{(A-7)}$$

where X_i is the input value from industry i to the passenger motor vehicle industry, $X_{i,AVE}$ is the input value from industry i to the average vehicle industry, and $X_{i,HYBRID}$ is the input value from industry i to the hybrid vehicle industry.

Because the inputs from the battery industry to the hybrid vehicle industry were ¥160 thousand higher per vehicle than the average vehicle, we calculated the value of input using the following equation:

[21] We used these prices to be consistent with the I-O table, although the calculated price is ¥0.13 million cheaper than that reported by Takeda (2012).

$$X_{BATTERY,AVE} = P_{BATTERY,AVE} \times Q_{AVE} = \left(\frac{X_{BATTERY} - 160{,}000 \times Q_{HYBRID}}{Q_{AUTO}} \right) \times Q_{AVE} \quad \text{(A-8).}$$

We also calculated the value of input from the battery industry to the hybrid vehicle industry by subtracting the value determined by equation (A-8) from the original input value, $X_{BATTERY}$.

We disaggregated the input from the motor vehicle parts and accessories industry using the following equation:

$$X_{PARTS,AVE} = \left(\frac{X_{PARTS} - 240{,}000 \times Q_{HYBRID}}{Q_{AUTO}} \right) \times Q_{AVE} \quad \text{(A-9).}$$

The value of input for the hybrid vehicle industry was determined by subtracting the value of equation (A-9) from the input value, X_{PARTS}.

The final step in the disaggregation of the column was to determine the value added for both the average vehicle and the hybrid vehicle. Value added is the difference between domestic production and the total of intermediate sectors. Using this definition, the value added to the domestic production ratio was 13.0% and 0.3% for the average vehicle and hybrid vehicle, respectively.

1.2 Disaggregation of the row

The disaggregation of the row is usually conducted using information on the industries' intermediate goods output, domestic final demand, export, import, and domestic production. The value of intermediate goods output is zero for the passenger motor vehicle industry in the original I-O table. In other words, the passenger motor vehicle industry does not supply any vehicles as intermediate goods to other industries. Thus, the disaggregation of the intermediate goods is not necessary for disaggregating the hybrid vehicle industry from the passenger motor vehicle industry.

We assumed that the import value for the hybrid vehicle industry is zero because there are no statistics on the value of imported hybrid vehicles for Japan. In addition, we assumed that the export value is zero for the hybrid vehicle industry. This assumption appears to be invalid at first glance, but because the model used to calculate the economic and labor impacts does not require exports to be disaggregated, this assumption can be used.

These two assumptions and the fact that the intermediate goods output is zero simplified the disaggregation of the row. The domestic final demand equals domestic production, Y_{HYBRID}, which was calculated in disaggregating the column.

2. Disaggregating the solar panel industry

Solar panels are produced by the other electrical devices and parts industry in the original I-O table.[22] Therefore, it is difficult to calculate the economic and labor impacts from an increase in exports of solar panels by the JCM. In this section, we describe the methods used to disaggregate the solar panel industry from the other electrical devices and parts industry.

2.1 Disaggregation of the column

The total domestic product, input ratio, and value-added ratio are needed to disaggregate the column for the other electrical devices and parts industry. The total domestic product of the solar panel industry was calculated using the figures provided by the Japan Photovoltaic Energy Association[23] and the Optoelectronics Industry and Technology Development Association (2011). The Japan Photovoltaic Energy Association provided data for the amount of domestic sales in kW, and the Optoelectronics Industry and Technology Development Association (2011) provided total domestic sales. Using these two figures, the average price of solar panels (i.e., price per kW) was calculated to be ¥245 thousand /kW.[24] The total domestic product for the solar panel industry was calculated using the average price and the domestic consumption and import and was found to be ¥539.341 billion in 2010. This value was used to disaggregate the original total domestic production for the other electrical devices and parts industry into the total domestic production for the other electrical devices and parts industry and the total domestic production for the solar panel industry. These figures were used in the column and row of the I-O table.

The value of input from the suppliers of intermediate goods to the solar panel industry and the other electrical devices and parts industry was calculated using the following two equations:

$$A_{i,Solar} = a_{i,Solar} \times X_{Solar} \qquad \text{(A-10)}$$

$$A^{*}_{i,Other} = A_{i,Other} - A_{i,Solar} \qquad \text{(A-11)}$$

[22] Examples of goods produced by the other electrical devices and parts industry include lead wires, silicon wafers, lamp sockets, tungsten wire for electrical lamps and electronics, permanent magnets, electrical contacts, and solar cells.
[23] The Japan Photovoltaic Energy Association provides annual data at their website (http://www.jpea.gr.jp/pdf/statistics/cellmodule_year_eng.pdf).
[24] The total shipment of solar panels was 2.538 million kW, and the total sales was ¥621.44 billion.

where $A_{i,Solar}$ and $A^{*}_{i,Other}$ denote the input from industry i to the solar panel industry and the other electrical devices and parts industry, respectively, and $A_{i,Other}$ is the input from industry i to the other electrical devices and parts industry listed in the I-O table.

The input value from industry i to the solar panel industry was derived by multiplying the total domestic product, X_{Solar}, by the input coefficient, $a_{i,Solar}$. We used the input coefficient provided by the Institute of Energy Economics Japan (2007); however, the figures provided contained missing or unknown values for some inputs. We estimated the input coefficient for these industries using the data provided by Nakano et al. (2008).

The input value from industry i to the other electrical devices and parts industry, $A^{*}_{i,Other}$, was calculated by subtracting the input value, $A_{i,Solar}$, for each industry from the original input value, $A_{i,Other}$, provided by the I-O table.

We then disaggregated the value added for the solar panel industry and the other electrical devices and parts industry. The methodology used in disaggregating the value added was similar to the disaggregation of the input value (i.e., multiplying the total domestic product for the solar panel industry by the value-added ratio). We then subtracted this figure from the original value-added figure to obtain the value added for the other electrical devices and parts industry.

2.2 Disaggregation of the row

The disaggregation of the row followed three steps: determining the total domestic product; disaggregating the intermediate goods supplied by the solar panel industry to other industries; and calculating domestic demand, exports, and imports.

We first determined the total domestic product for the solar panel industry,[25] which was calculated at ¥539.341 billion. Then, we disaggregated the intermediate goods supplied from the solar panel industry to other industries. We were not able to obtain information concerning the intermediate goods demand for the solar panel industry. Thus, for simplicity, we assumed that there was no intermediate demand for solar panels.

[25] The calculation of the total domestic product for the solar panel industry was discussed in the previous subsection.

The final step involved calculating the domestic demand, export, and import of solar panels. The Japan Photovoltaic Energy Association provided data on domestic consumption, export, and import in kW. We used these figures, along with the average price per kW, to calculate the domestic demand, export, and import of solar panels. Table A-1 shows the calculation results for each of the components needed in the disaggregation of the row.

Table A-1. Values for Disaggregation of the Row

Item	Value (billion yen)
Domestic Demand	219.126
Export	361.264
Final Domestic Demand	580.390
Import	41.049
Total Domestic Production	539.341

Appendix B   Sensitivity Analysis for the Hybrid Vehicle Industry

The calculations in our study included the value-added ratio of 0.3%. However, an informal interview with the automobile industry revealed that the value-added ratio was actually negative until recently. Therefore, the value-added ratio of 0.3% may not represent the situation in 2010.
We conducted a sensitivity analysis to determine the effects of change in the value-added ratio on economic and labor impacts.

Table B-1 shows the results due to the change in value-added ratio ranging from 13% to -10%.[26] The results show that as the value-added ratio declines, the economic impacts rise. The labor impact also rises with the economic impacts.

Table B-1. Results from Sensitivity Analysis

Value Added Ratio	Economic Impacts (billion yen)	Labor Impacts (Number of Jobs)
13%	30.53	859
10%	31.45	893
0.30%	33.75	980
-5%	35.02	1,027
-10%	36.22	1,072

[26] Thirteen percent was used because this value was the same as that of the average vehicle.