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Abstract Corporate social responsibility is imperative for manufacturing companies to achieve sustainable development. Under a strong environmental information disclosure system, polluting companies are disadvantaged in terms of market competitiveness because they lack an environmentally friendly image. The objective of this study is to analyze the productive inefficiency change in relation to toxic chemical substance emissions for the US and Japan and their corresponding policies. We apply the weighted Russell directional distance model to measure companies' productive inefficiency which represents their production technology. The data encompass 330 US manufacturing firms observed from 1999 to 2007, and 466 Japanese manufacturing firms observed from 2001 to 2008. This paper focuses on nine high-pollution industries (rubber and plastics; chemicals and allied products; paper and pulp; steel and nonferrous metal; fabricated metal; industrial machinery; electrical products; transportation equipment; precision instruments) categorized into two industry groups: basic materials industries and processing and assembly industries. The results show that the productive inefficiency decreased in all industrial sectors in the US and Japan from 2001 to 2007. In particular, that of the electrical products industry decreased rapidly after 2002 for both countries, possibly because of the enforcement of strict environmental regulations for electrical products exported to European markets.

Keywords: productive inefficiency; weighted Russell directional distance model; toxic chemical substances; manufacturing sector; United States; Japan

Introduction

Corporate social responsibility is imperative for manufacturing companies to achieve sustainable development. Although companies engage in production activity to achieve the key objective of economic development, the production processes of manufacturing companies generate a significant amount of environmental pollution. In many cases, the environmental burden generated by certain production processes depends on the design of products and services.

The best-known definition of sustainable development is that given by the World Commission on Environment and Development (WCED), which promotes closer links between the environment and development. The Brundtland report, *Our Common Future* (WCED, 1987), defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. This definition is rather indefinite and raises more questions than it answers. A more precise definition would be, for example, development that requires utility levels, resource stocks, or total capital stocks, including natural capital and human capital, to be nondecreasing over time. Thus, sustainable paths tackle standard optimal solutions as formalized in the traditional theory of economic growth (Akao and Managi, 2007).

A key element in sustainable development is a decrease in productive inefficiency. Productive inefficiency relates to the use of resources in production. Manufacturing firms use several resources as inputs, including labor, capital, and intermediate products. The allocation of resources and strategy differs between companies, and these resource allocation differences generate productive inefficiency (Fujii *et al*, 2010). Productive inefficiency contributes to the consumption of more intermediate materials than needed for production, which generates additional environmental pollutants by the manufacturing companies. Thus, continuous productive inefficiency decrease (or efficiency increase), which includes pollution reductions, is important for achieving sustainable development. Against this background, this study analyzes productive inefficiency in light of environmental policies on the provision and dissemination of environmental information in the US and Japan.

The principal task of this study is to measure productive inefficiency and decompose it into input factor inefficiency, desirable output factor inefficiency, and undesirable output factor inefficiency. It is important to note that we cannot judge whether the inefficiency decreases over time a priori. This is because regulations requiring more stringent pollution abatement do not necessarily change the productive inefficiency[1].

This study targets US and Japanese manufacturing firms for three reasons. First, they are large emitters. In 2008, the US and Japanese industrial sectors emitted 3.85 billion and 0.44 billion pounds of chemical substances, respectively - amounts that are larger than for any other developed country. As Lanjouw and Mody (1996) noted, the US and Japan spend large amounts on research and development for environmentally desirable technology, and both countries have a high ratio of environmental patents to the total number of patents. Second, for both countries, pollution abatement costs and expenditures make up large shares of the GDP. Finally, the US and Japanese governments provide free pollution release and transfer register (PRTR) information for companies on their websites, thus ensuring easy dissemination of environmental information to the public. This study considers the differences between industries and compares the productive inefficiencies for nine manufacturing industries in the US and Japan.

We begin by providing background information about the PRTR system in the US and Japan. We then introduce some related literature on productive inefficiency analysis and methodology. Following that, we explain our data and discuss the results. The final section presents further discussion and concluding remarks.

Background

In 1984, there was an accidental explosion at a pesticide plant in India; not long afterward, there was a leak at a US chemical plant. These accidents triggered an international movement to better understand the use of toxic chemical substances. Demand for information on toxic chemicals being released outside of the facilities was accelerated by public interest and environmental organizations (Khanna *et al*, 1998). This led to the enactment of the US Emergency Planning and Community Right-to-Know Act (EPCRA) in 1986, which established the Toxics Release Inventory (TRI) is a publicly available US Environmental Protection Agency (EPA) database that contains information on toxic chemical releases reported annually by both certain industries and federal facilities[2].

The PRTR system in Japan has been in force since 2001, with the first public release of PRTR data on March 20, 2003. Under the PRTR system, facilities that have more than 20 employees and produce or use chemicals on a list of 354 substances specified by the law must annually report their quantities to the central government. The central government aggregates and sorts the reported data by industry type and geographic location, and the aggregated information is then provided to the public. The

PRTR in Japan has an important role in reducing and managing the development of toxic chemicals.

We provide a historical review of environmental regulations dealing with toxic chemical substances in the US and Japan in Table 1. As shown in the table, Japan’s pollution restriction laws date back to the end of the 1960s, whereas the US was enforcing such laws in the 1940s and 1950s. In the US in 1986, the EPCRA established the TRI; the US government went on to implement a unique plan known as the 33/50 Program, launched in 1991. The 33/50 Program targeted 17 priority chemicals, including toluene and benzene, and set a goal of a 33% reduction in release and transfer of these chemicals by 1992 and a 50% reduction by 1995, measured against a 1988 baseline. The primary purpose of this voluntary program was to demonstrate the benefits of voluntary partnerships. Many previous studies support the benefits of voluntary approaches in bringing about targeted reductions more quickly than would regulations alone (e.g., Zatz and Harbour, 1999; Vidovic and Khanna, 2007). From 2006, Japan started its volatile organic compounds (VOC) reduction plan, which has a target of a 30% reduction in release of VOC chemical substances, based on the voluntary effort of manufacturing firms and business associations.

< Table 1 about here >

Literature Review and Methodology

Literature review

The issue of whether pollution abatement technologies are applied effectively is an important empirical question (Kolominskas and Sullivan, 2004). This is because the use of technology influences the production cost and pollution abatement cost and expenditures (e.g., Jaffe *et al*, 2005). There are two conflicting incentives that affect whether environmental regulations encourage or discourage decreases in productive inefficiency (Managi *et al*, 2005). On the one hand, abatement pressure might encourage productive inefficiency decreases that reduce the actual compliance costs to a level below those originally estimated (Bunge *et al*, 1996). On the other hand, firms might be unwilling to decrease their productive inefficiency if they believe regulators will respond by gradually tightening standards even further. In addition to changes in environmental standards and technology, environmental management levels affect productive inefficiency. Therefore, whether the productive inefficiency decreases over time is an empirical question (Managi *et al*, 2005).

There is a range of empirical evidence on the link between pollution abatement technology and economic performance. Claver *et al* (2007) analyzed a single agricultural cooperative company in Spain in terms of the relationship between corporate environmental management (CEM) and economic performance; their results indicate that proactive CEM can enhance both environmental and economic performance. The literature on environmental standards and environmental innovations also covers various other situations, including automobile companies in France (Oltra and Saint-Jean, 2009) and appliance manufacturers in Germany (Kammerer, 2009). Two types of studies that focus on productive inefficiency in relation to toxic chemical substances can be identified: one type focuses on the whole industrial sector, and the other examines firm-level data. If we apply data for the whole industrial sector to estimate productive inefficiency, the industry's structural characteristics largely affect the productive inefficiency. In contrast, most studies that use firm-level data focus on only one industrial sector (e.g., Färe *et al*, 2001; Kwon, 2006; Koehler and Spengler, 2007; Fujii *et al*, 2010; Fujii *et al*, 2011). Although in each country the PRTR system came into force for all industrial sectors in the same year, the technical difficulty of achieving reductions in emissions of toxic chemical substances differs between industries. In addition, it is clear that different industries require different capital equipment and labor to reduce toxic chemical substances, because the chemical products that are consumed as intermediate materials are different. We therefore compare the sector-level productive inefficiency in relation to emissions of toxic chemical substances.

This study measures productive inefficiency in the US and Japanese manufacturing firms. We apply the weighted Russell directional distance model (WRDDM) to measure productive inefficiency using production technology following Chen *et al* (2011) and Barros *et al* (2011). They proposed a measure based on directional distance function, which is evaluated in linear form, and hence processes the attractive advantages of easy computation and easy extension of incorporating the additional undesirable outputs into the programming problems.

Methodology (WRDDM)

Let inputs be denoted by $x \in R_+^N$, good outputs by $y \in R_+^M$, and bad or undesirable outputs by $b \in R_+^L$. The directional distance function seeking to increase the desirable outputs and decrease the undesirable outputs and inputs directionally can be defined by the following:

$$\vec{D}(x, y, b; g) = \sup\left\{\beta : (x - \beta g_x, y + \beta g_y, b - \beta g_b) \in T\right\}, \tag{1}$$

where the nonzero vector $g = (-g_x, g_y, -g_b)$ determines the directions in which inputs, desirable outputs, and undesirable outputs are scaled. The technology reference set T = {(x, y, b): *x can produce* (y, b)} satisfies strong disposability of desirable outputs and inputs, and weak disposability of undesirable outputs.

Suppose there are $j = 1, \ldots, k, \ldots J$ decision-making units (DMUs) in the dataset. Each DMU uses inputs $x = (x_1, x_2, \ldots, x_N) \in R_+^N$ to jointly produce desirable outputs $y = (y_1, y_2, \ldots, y_M) \in R_+^M$ and undesirable outputs $b = (b_1, b_2, \ldots, b_L) \in R_+^L$. The WRDDM for inefficiency calculation of DMU k can be described as follows:

$$\mathrm{D}(\mathrm{x}, \mathrm{y}, \mathrm{b}; \mathrm{g}) = \text{maximize}\left(\frac{1}{N}\sum_{n=1}^{N}\beta_n^k + \frac{1}{M}\sum_{m=1}^{M}\beta_m^k + \frac{1}{L}\sum_{l=1}^{L}\beta_l^k\right) \tag{2}$$

subject to

$$\sum_{j=1}^{J} z_k y_{mj} \geq y_{mk} + \beta_m^k \mathrm{g}_{ymk} \tag{3}$$

$$\sum_{j=1}^{J} z_k b_{lj} = b_{lk} - \beta_l^k \mathrm{g}_{blk} \tag{4}$$

$$\sum_{j=1}^{J} z_k x_{nj} \leq x_{nk} - \beta_n^k \mathrm{g}_{xnk} \tag{5}$$

$$Z_j \geq 0,\ \ j = 1,2,\cdots,k,\cdots,J, \tag{6}$$

where β^k_m, β^k_l, and β^k_n are the individual inefficiency measures for desirable outputs, undesirable outputs, and inputs, respectively. Z_k are the intensity variables to shrink or expand the individual observed activities of DMU k for the purpose of constructing convex combinations of the observed inputs and outputs. By setting $\mathrm{g} = \left(-\mathrm{g}_{xnk}, \mathrm{g}_{ymk}, -\mathrm{g}_{blk}\right) = (-x_{nk}, y_{mk}, -b_{lk})$, the WRDDM with variable returns to scale is shown as follows:

$$\mathrm{D}(\mathrm{x},\mathrm{y},\mathrm{b};\mathrm{g}) = maximize\left(\frac{1}{N}\sum_{n=1}^{N}\beta^k_n + \frac{1}{M}\sum_{m=1}^{M}\beta^k_m + \frac{1}{L}\sum_{l=1}^{L}\beta^k_l\right) \tag{7}$$

subject to

$$\sum_{j=1}^{J} z_k y_{mj} \geq y_{mk}(1+\beta^k_m) \tag{8}$$

$$\sum_{j=1}^{J} z_k b_{lj} = b_{lk}(1-\beta^k_l) \tag{9}$$

$$\sum_{j=1}^{J} z_k x_{nj} \leq x_{nk}(1-\beta^k_n) \tag{10}$$

$$Z_j \geq 0,\ \ j = 1,2,\cdots,k,\cdots,J. \tag{11}$$

This type of directional vector assumes that an inefficient firm can decrease productive inefficiency while increasing desirable outputs and decreasing undesirable outputs and/or inputs in proportion to the initial combination of actual inputs and outputs.

One of the strong points of the WRDDM is that it is able to determine each variable's contribution ratio for inefficiency. This contribution ratio cannot be determined in conventional productive inefficiency analysis. The contribution ratios enable us to discuss how and why each industry successfully decreased its productive inefficiency.

Data and Results

Data

The financial dataset for the US firms comes from the Mergent Online financial database, and the chemical substances data are taken from the EPA's TRI database. The financial dataset for the Japanese firms is provided by the Nikkei NEEDS financial database, and the chemical substances data are taken from the PRTR database from the Ministry of Economy, Trade, and Industry (METI). Japanese manufacturing firm-level data cover the eight years from 2001 to 2008 and the US manufacturing data cover the nine years from 1999 to 2007. Data for 466 Japanese firms and 330 US firms were included (see Table 2). This paper focuses on nine industries: (1) chemicals; (2) fabricated metal; (3) pulp and paper; (4) rubber and plastics; (5) steel and nonferrous metal; (6) electrical products; (7) industrial machinery; (8) precision instruments; and (9) transportation equipment. We group these nine sectors into two categories: basic materials industries and processing and assembly industries (Table 2).

<Table 2 about here>

To analyze productive inefficiency, we use the following variables. Total revenue of the firm is used as the market output variable, and capital stock, number of employees and intermediate material inputs are used as market input variables. These financial variables are deflated by the 2000 year price by type of industry. Deflators for the US firms are taken from the OECD database. Deflators for the Japanese firms come from the Statistics Bureau and the Bank of Japan database. The integrated toxic chemical substances risk score (toxic risk score), which is estimated by using the toxicity weight given by the US EPA, is used for undesirable outputs for productive inefficiency estimation.

There are three limitations with our data. The first is related to the data coverage of firm data. The Mergent Online database provides consolidated financial data and, therefore, the TRI database includes parent company names. We used this code to integrate each plant's toxic chemical substance emission data into consolidated company-level data. In contrast, the Japanese PRTR database does not include parent company names; it only includes nonconsolidated company names. We therefore integrated the Japanese PRTR data into nonconsolidated, company-level data. The second limitation is the difference in coverage of the number of chemical substances between the US and Japan. There are 426 chemical substances in the TRI database published by the US EPA, and the toxicity weight applies to all of them. In contrast, there are 354 chemical substances in the PRTR published by the METI in Japan, and the toxic weight applies to only 134 of them. This mismatching makes it difficult to compare the toxic risk scores directly. Therefore, we focus more on the time series of the productive inefficiency change in each country and industry. The third limitation is that, although we use capital stock data for the Japanese firm analysis, comprehensive capital stock data are not available for the US firms. We therefore apply net property plant and equipment as capital stock for the US firm analysis. In general, the value of net property plant and equipment is lower than that of capital stock because, unlike capital stock, these items do not include intangible assets.

The results are given in Figures 1 to 4 and Tables 3 and 4. The figures show the industrial average inefficiency score, and the tables show the industrial average contribution ratio for each inefficiency score.

Results for the US industries

From Figure 1, we find that the productive inefficiency of the fabricated metal industry increased from 1999 to 2000, and then decreased after 2000. However, the productive inefficiencies of the rubber and paper industries decreased from 2002 to 2007. The productive inefficiency of the steel industry did not change from 1999 to 2002, but subsequently it decreased. To examine these productive inefficiency results in more detail, we focus on the contribution ratio for the inefficiency score. As shown in Table 1, the rubber and chemical industries decreased their inefficiency scores without changing the combination ratio. This means that a decrease in productive inefficiency can be achieved by improving both use of input factors and production of outputs. The contribution ratio of the metal industry changed from 1999 to 2000, especially for capital, sale, and toxic. This change in contribution ratio implies that the main contributor toward the productive inefficiency score shifted from capital productivity to toxic chemical substance emission performance. We believe that the main reason the inefficiency score of the metal industry worsened is that the toxic risk score of chemical substance emissions from the metal industry increased.

We now discuss the results for the processing and assembly industries (see Figure 2). Productive inefficiency decreased in all industries, showing a similar trend across the entire group from 1999 to 2007. Furthermore, the productive inefficiency decreased more rapidly in the processing and assembly industries than in the basic materials industries, especially in the electrical products and precision instruments industries. One explanation for this rapid decrease is that this period saw considerable technological innovations in the information technology field, which would have affected, for example, the semiconductor and the electronic components industry. In particular, processing and assembly companies invested large amounts of capital and expenditure in research and development to enable innovations and develop new products.

Another reason for the decrease in productive inefficiency in the processing and assembly industries might be related to the enforcement of environmental standards in Europe. Because European environmental regulations stipulated threshold amounts of toxic chemical substances, electrical products exported from the US to Europe had to meet these restrictions in order to comply. Europe has three strict environmental standards for the processing and assembly industries: (1) restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS); (2) end-of-life vehicles directive (ELV)[3]; and (3) registration, evaluation, authorization and restriction of chemicals (REACH). Under the RoHS and ELV directives, no electrical or vehicle products that contain levels of toxic chemicals above the set amount can be sold in the European market. Because of these strict environmental standards, US firms that export to the European market had to promote toxic chemical substance management. Therefore, the decrease in productive inefficiency in the processing and assembly industries was mainly driven by two factors: rapid technological advances and strict environmental standards in the European market.

Further, the WRDDM result shows a poor financial performance by the transportation industry. One interpretation of this result is that environmentally proactive firms developed better toxic chemical substance management systems because of the new environmental standards, but that some firms may have chosen to retain their reactive environmental management to minimize the costs of environmental protection. This can arise because the TRI system does not actually regulate toxic chemical emissions. That is, firms that concentrate on the domestic market might have fewer incentives to reduce their emissions of toxic chemical substances. As the processing and assembly industries tend to export to the European market, they have incentives to manage their toxic chemicals proactively and must adjust to stringent environmental standards such as the RoHS and the ELV. These proactive firms reduce their consumption and emissions of toxic chemical substances efficiently. Therefore, firms that do not export to the global market might also be affected through supply chain management, although this effect is limited. Hence, firms' perceptions of environmental preferences and environmental standards differ, which might be one reason why some firms manage toxic chemical substances well and others do not. Another explanation could be that the processing and assembly industries mainly use chemical substances for paint and bonding, and firms can reduce toxicity by replacing highly toxic chemicals with less toxic chemical materials. Although changing to less toxic chemical substances is costly, technological innovations can reduce the cost and resolve constraints such as bonding ability and color quality. Therefore, by introducing less toxic chemical materials, inefficient firms could achieve reduced toxicity.

<Figure 1 about here>

<Figure 2 about here>

<Table 3 about here>

Results for the Japanese industries

From Figure 3, we find that the productive inefficiencies of five Japanese basic materials industries decreased from 2001 to 2007. In particular, the chemical industry's productive inefficiency rapidly decreased. However, the productive inefficiencies of the steel and fabricated metal industries increased in 2008 because of the financial crisis.

As Table 4 shows, the contribution ratio of toxic chemical substances increased from 2001 to 2008 in most industries. Furthermore, the productive inefficiency score, shown in Figure 3, decreased. This gives us to understand that the main contributor toward decreases in productive inefficiency was a reduction in emissions of toxic chemical substances. In examining the toxic chemical substances data in detail, we found that the level of VOC emissions fell more rapidly than those of other chemical substances, especially from 2006 to 2008, possibly because of the VOC restrictions introduced in 2006. Japan's environmental standards establish seminars and workshops to help manufacturing companies and business associations reduce their use of VOC chemical substances. These activities support small- and medium-scale firms that tend to experience difficulty in reducing their use of VOC chemical substances because they lack the necessary money and knowledge.

The productive inefficiency of the rubber, chemical, and paper industries also decreased rapidly. In particular, the chemical industry greatly decreased its toxic risk score from 2001 to 2008, because of the proactive approach of the Japanese Chemical Industry Association (JCIA)[4]. The JCIA launched its own PRTR system as early as 1997 to determine the amounts of toxic chemical substances emitted and moved. The JCIA also held workshops and seminars to spread their ideas for reducing toxic chemical substances effectively and cheaply among member firms. This progressive approach helped small-scale firms, which tended to be reactive to requirements to reduce emissions of toxic chemical substances, without straining their corporate financial performance.

We now turn to the results for the Japanese processing and assembly industries (see Figure 4). This group of industries decreased their overall productive inefficiency from 2001 to 2008, especially the electrical products industry, which dramatically decreased its inefficiency. As noted for the US processing and assembly industries, these industries mainly use toxic chemical materials for paint and bonding, which can be replaced with less toxic chemical materials relatively easily. However, the toxic chemical materials used in the basic materials industries are very specific and hence difficult to replace. Consequently, processing and assembly industries have an advantage over basic materials industries in reducing their toxic risk scores.

The REACH directive, which came into force in Europe in 2006, induces firms that export to the European market to be more proactive in their efforts to control toxic chemical substances. The REACH directive is planned to cover, by 2018, 30,000 chemical substances that firms treat at a volume of more than one tonne per year. To meet this stringent environmental standard while maintaining international market competitiveness, progressive firms must spread knowledge and solve problems together through seminars and workshops by all business associations. Furthermore, the REACH directive induces firms to develop comprehensive environmental management strategies through supply chain management and become more efficient in procuring environmentally friendly materials.

A comparison of the results for the US and Japan reveals several points of difference. From Tables 3 and 4, we see that the combination of the contribution ratio of Japanese firms was different from that of US firms. In many Japanese industries, the contribution ratio of toxic increased whereas the contribution ratio of sale tended to decrease year by year. This implies that the main contributor toward the change in productive inefficiency switched from sale to toxic. One possible explanation for this is that the PRTR was introduced in Japan in 2001, and both efficient firms and inefficient firms were started on a steep learning curve for toxic chemical substance management (i.e., lower marginal pollution abatement). However, US manufacturing firms had more time to prepare for toxic chemical substance management because the TRI had been introduced there in 1986, and environmentally proactive firms might have already begun to apply cost-efficient pollution abatement technologies.

<Figure 3 about here>

<Figure 4 about here>

<Table 4 about here>

Conclusion

Corporate social responsibility is an important concept for companies seeking to achieve a balance between their economic development and environmental protection. In particular, toxic chemical substance management has become a higher-priority target for manufacturing firms since the discussion on biodiversity protection intensified at the Conferences of the Parties (COP). This study analyzed productive inefficiency in relation to emissions of toxic chemical substances, and compared the results for Japan and the US.

This paper makes several contributions to the literature on changes in productive inefficiency. Environmental policy instruments that contain provisions on releasing information in pollutants have emerged in recent years as mainstream regulatory tools. To explore how such provisions provide firms with an incentive to improve their environmental performance, we analyzed and compared various industries' environmental performance in terms of productive inefficiency.

The main finding of this study is that productive inefficiency decreased in all sectors in the manufacturing industry in the US and Japan from 2001 to 2007. In particular, the productive inefficiency of the electrical products industry decreased rapidly after 2002. These decreases might be the result of enforcement of the RoHS and REACH directives in Europe. US and Japanese companies that export to the European market have strong incentives to manage toxic chemical substances in order to comply with the strict restrictions on toxic chemical substances.

This study contributes to the productive inefficiency literature in the following two points. First, the paper determines the contribution ratio for the productive inefficiency score by industrial sector, which has not been the focus of any previous research. The contribution ratio is useful for clarifying why and how productive inefficiency changes according to the types of input–output variables applied. Second, the paper measures productive inefficiency in terms of toxic chemical emissions by sector. Many previous studies used overall industry data without examining the particular characteristics of different sectors. It is important for policymakers and corporate decision makers to understand changes in productive inefficiency at the sector level because the labor input and pollution abatement equipment needed to reduce toxic chemical substances differ by sector.

Corporate social responsibility is imperative for manufacturing firms seeking to to achieve sustainable development by balancing environmental pollution reduction and corporate financial performance. Future research is necessary to determine the multiple dimensions of environmental pollution, including CO_2 emissions and resource consumption.

Note

1. This is so because the linear expansion of pollution abatement costs and pollution reduction does not necessarily change the pollution reduction per abatement cost (Pethig, 2006).

2: Reports for the TRI must be filed by the owners and operators of facilities that meet all of the following criteria: (1) TRI reporting requirements are limited to manufacturing facilities with major standard industrial classification (SIC) code groups 20 through 39. In 1997, the US EPA added another seven industry sectors to the TRI requirements. These sectors started to submit reports from 1998. (2) The number of full-time employees must be 10 (or the equivalent of 20,000 hours of work per year) or more. (3) Any facility that manufactured or processed more than 25,000 pounds or otherwise used more than 10,000 pounds of a listed toxic chemical during the course of the calendar year is required to submit a report.

3: The RoHS, REACH, and ELV were promulgated in 2003, 2006, and 2000 and came into force in 2006, 2007, and 2003, respectively.

4: The Japan Chemical Industry Association (JCIA) has nearly 180 member companies, with 80 organizations engaged in the manufacturing and handling of chemical products and related services. The JCIA has actively undertaken activities to fulfill its mission of promoting the balance between economic development and environmental protection.

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Table 1. History of law and regulation about toxic chemical substances

Year	Japan	United State
-1985	- Basic Law for Environmental Pollution (1967-1993) - Air Pollution Control Law (1968) - Water Pollution Control Law (1970) - Chemical Substances Control Law (1973)	-Clean Water Act (1948) (Revised in 1972,1977,1987) -Clean Air Act (1955) (Revised in 1970,1977,1990.) -Toxic Substances Control Act (1976)
1985-1989	-Amendment of chemical Substances Control Law (1986)	-Emergency Planning and Community Right-to-Know Act was enacted (1986) -Toxic Release Inventory (TRI) started (1986)
1990-1994	- Law Concerning Special Measures for Total Emission Reduction of Nitrogen Oxides and Particulate Matte (1992) - Basic Environment Law (1993) - The Basic Environmental Plan (Define concept of environmental risk) (1994)	-EPA establishes the 33/50 Program (1991) -Expansion of the chemical list raised the number of chemicals and chemical categories reported to TRI from 336 to over 600 (1994)
1995-1999	- Pollutant Release and Transfer Registers Law [PRTR Law] (1999)	-Facility/industry expansion[1](1997) -Chemical Use Reporting[2](1997)
2000-2004	- Law Concerning Special Measures against Dioxins (2000) -Amendment of Chemical Substances Control Law (2003)	-EPA held an on-line public dialogue on options for reducing the burden on the regulated industry associated with the Toxics Release Inventory (TRI) program (2003)
2005-2009	- Amendment of Air Pollution Control Law [start restriction of VOC emission] (2006) - Basic Act on Biodiversity (2008)	- EPA revised the TRI reporting requirements to reduce burden and promote recycling and treatment as alternatives to disposal and other releases (2006) - TRI Form A Eligibility Implementing the 2009 Omnibus Appropriations Act (2009)

Source: U.S. EPA homepage, http://www.epa.gov/
Ministry of Environment, Japan homepage, http://www.env.go.jp/en/

Table 2. Firms by industry type

Industry type	Type of business	Code	U.S.	Japan
Basic Material industry	Chemicals and allied products	CHEM	54	122
	Fabricated metal	METAL	19	28
	Paper and Pulp	PAPER	16	19
	Rubber and Plastic products	RUBB	14	43
	Steel ,Non-ferrous metal	STEEL	23	63
Processing and assembly industry	Electric product	ELEC	78	30
	Industrial Machine	MACHINE	49	68
	Precision instrument	PREC	38	24
	Transportation equipment	TRANS	39	69

Source: Author created

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[1] Seven new industry sectors are added.

[2] Expansion of the TRI to gather chemical use information and Expansion of the EPA Community Right-to-Know Program to increase the information available to the public on chemical use.

Table 3. Contribution ratio for inefficiency score of U.S. manufacturing companies

		Indicator	1999	2000	2001	2002	2003	2004	2005	2006	2007
Basic material industry	CHEMI	COST of SALE	5%	4%	4%	5%	5%	5%	5%	5%	5%
		CAPITAL	1%	1%	1%	1%	1%	1%	1%	1%	2%
		LABOR	3%	3%	3%	3%	2%	3%	3%	3%	3%
		SALE	42%	41%	45%	45%	43%	40%	45%	42%	43%
		TOXIC	48%	50%	47%	46%	49%	51%	46%	49%	48%
	METAL	COST of SALE	1%	2%	2%	2%	1%	1%	1%	2%	2%
		CAPITAL	19%	10%	11%	13%	12%	14%	12%	13%	13%
		LABOR	8%	5%	3%	3%	2%	2%	4%	2%	2%
		SALE	30%	12%	11%	16%	13%	14%	13%	10%	9%
		TOXIC	42%	71%	72%	66%	72%	69%	70%	74%	74%
	PAPER	COST of SALE	10%	11%	13%	7%	2%	3%	2%	2%	0%
		CAPITAL	1%	1%	1%	5%	14%	12%	13%	12%	9%
		LABOR	4%	4%	5%	5%	2%	1%	3%	1%	0%
		SALE	6%	10%	14%	18%	14%	12%	14%	13%	12%
		TOXIC	79%	74%	68%	64%	68%	72%	69%	73%	79%
	RUBB	COST of SALE	11%	11%	10%	10%	9%	11%	9%	9%	8%
		CAPITAL	1%	1%	0%	2%	1%	2%	2%	1%	2%
		LABOR	6%	5%	5%	5%	3%	1%	3%	3%	3%
		SALE	9%	7%	8%	9%	5%	3%	3%	8%	7%
		TOXIC	73%	76%	76%	75%	81%	83%	82%	79%	80%
	STEEL	COST of SALE	0%	0%	0%	0%	0%	0%	0%	0%	0%
		CAPITAL	10%	8%	9%	10%	9%	11%	8%	10%	8%
		LABOR	14%	13%	13%	12%	12%	16%	11%	13%	11%
		SALE	5%	6%	5%	4%	5%	4%	4%	2%	1%
		TOXIC	72%	73%	73%	74%	74%	70%	78%	75%	79%
Processing and assembly industry	ELEC	COST of SALE	2%	2%	3%	3%	2%	2%	2%	3%	3%
		CAPITAL	0%	0%	0%	0%	0%	0%	0%	0%	0%
		LABOR	5%	6%	5%	5%	5%	6%	7%	7%	7%
		SALE	66%	62%	59%	62%	57%	53%	48%	46%	46%
		TOXIC	26%	30%	33%	30%	35%	39%	43%	43%	44%
	MACHINE	COST of SALE	0%	1%	1%	1%	1%	1%	1%	1%	0%
		CAPITAL	11%	13%	13%	12%	12%	11%	12%	12%	12%
		LABOR	8%	10%	9%	9%	9%	10%	10%	10%	10%
		SALE	39%	32%	32%	28%	27%	23%	22%	20%	20%
		TOXIC	41%	45%	44%	50%	50%	55%	54%	57%	57%
	PREC	COST of SALE	3%	4%	4%	4%	4%	0%	1%	0%	0%
		CAPITAL	0%	0%	0%	0%	0%	4%	4%	4%	7%
		LABOR	6%	7%	7%	7%	6%	6%	8%	8%	9%
		SALE	60%	52%	43%	44%	45%	38%	34%	32%	36%
		TOXIC	31%	37%	45%	46%	45%	52%	54%	56%	49%
	TRANS	COST of SALE	0%	0%	0%	0%	0%	0%	0%	0%	0%
		CAPITAL	12%	13%	13%	13%	13%	11%	10%	9%	11%
		LABOR	12%	13%	14%	13%	13%	12%	11%	10%	10%
		SALE	3%	4%	5%	6%	5%	4%	5%	3%	2%
		TOXIC	72%	70%	68%	68%	68%	73%	74%	77%	77%

Source: Author created

Table 4. Contribution ratio for inefficiency score of Japanese manufacturing companies

		Indicator	2001	2002	2003	2004	2005	2006	2007	2008
	CHEMI	COST of SALE	7%	7%	8%	9%	9%	10%	9%	10%
		CAPITAL	1%	1%	2%	2%	2%	3%	3%	3%
		LABOR	2%	2%	1%	1%	1%	1%	1%	1%
		SALE	65%	63%	61%	58%	56%	50%	47%	45%
		TOXIC	26%	27%	28%	30%	32%	36%	40%	42%
	METAL	COST of SALE	6%	6%	7%	8%	9%	10%	4%	3%
		CAPITAL	2%	3%	3%	4%	4%	4%	7%	5%
		LABOR	2%	2%	1%	1%	1%	2%	3%	2%
		SALE	36%	33%	33%	29%	26%	21%	18%	46%
		TOXIC	53%	56%	56%	58%	60%	63%	68%	45%
	PAPER	COST of SALE	7%	6%	6%	6%	7%	7%	2%	2%
		CAPITAL	0%	1%	1%	0%	1%	1%	2%	2%
		LABOR	4%	3%	3%	3%	3%	3%	3%	4%
		SALE	22%	21%	22%	22%	17%	16%	6%	4%
		TOXIC	67%	69%	69%	69%	72%	74%	87%	87%
	RUBB	COST of SALE	8%	8%	9%	10%	10%	11%	5%	5%
		CAPITAL	0%	0%	1%	1%	1%	1%	3%	3%
		LABOR	2%	2%	2%	2%	2%	3%	4%	4%
		SALE	50%	49%	42%	38%	36%	30%	29%	25%
		TOXIC	40%	40%	45%	48%	51%	55%	59%	63%
	STEEL	COST of SALE	2%	2%	2%	2%	2%	2%	3%	2%
		CAPITAL	1%	1%	1%	1%	1%	1%	1%	2%
		LABOR	6%	6%	5%	5%	5%	5%	7%	9%
		SALE	39%	38%	38%	33%	37%	32%	21%	26%
		TOXIC	53%	54%	54%	58%	55%	61%	67%	61%
Processing and assembly industry	ELEC	COST of SALE	5%	5%	7%	9%	11%	13%	11%	12%
		CAPITAL	0%	0%	0%	1%	1%	1%	1%	0%
		LABOR	1%	1%	2%	2%	3%	3%	3%	4%
		SALE	70%	67%	59%	53%	44%	37%	36%	32%
		TOXIC	24%	26%	32%	35%	42%	47%	50%	51%
	MACHINE	COST of SALE	4%	6%	6%	7%	8%	7%	8%	8%
		CAPITAL	0%	0%	0%	0%	1%	1%	1%	1%
		LABOR	2%	2%	1%	2%	1%	1%	2%	3%
		SALE	54%	49%	48%	41%	37%	37%	20%	19%
		TOXIC	40%	43%	45%	50%	53%	54%	70%	69%
	PREC	COST of SALE	6%	7%	8%	9%	6%	7%	2%	4%
		CAPITAL	1%	0%	0%	1%	0%	0%	0%	0%
		LABOR	5%	5%	5%	4%	4%	3%	3%	3%
		SALE	35%	34%	28%	26%	30%	26%	30%	29%
		TOXIC	54%	54%	58%	60%	60%	63%	65%	64%
	TRANS	COST of SALE	1%	1%	1%	1%	1%	1%	1%	1%
		CAPITAL	1%	2%	2%	2%	2%	3%	3%	3%
		LABOR	5%	5%	5%	4%	4%	5%	6%	8%
		SALE	36%	34%	32%	30%	27%	23%	12%	7%
		TOXIC	57%	59%	60%	63%	65%	68%	78%	81%

Source: Author created

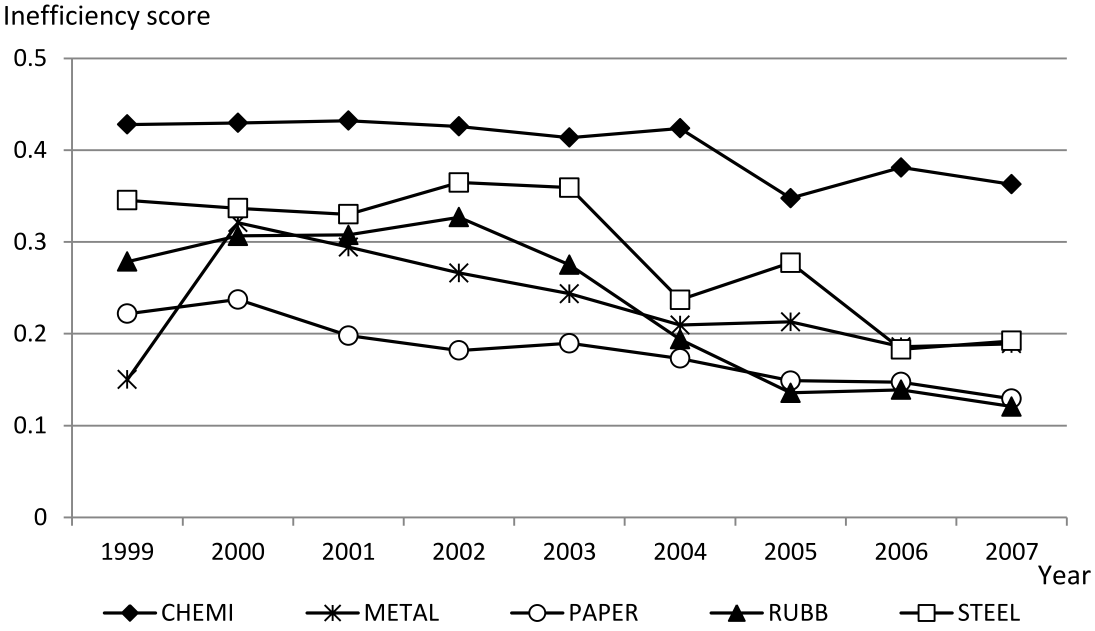

Figure 1. Inefficiency score change of U.S. basic material industry from 1999 to 2007

Source: Author created

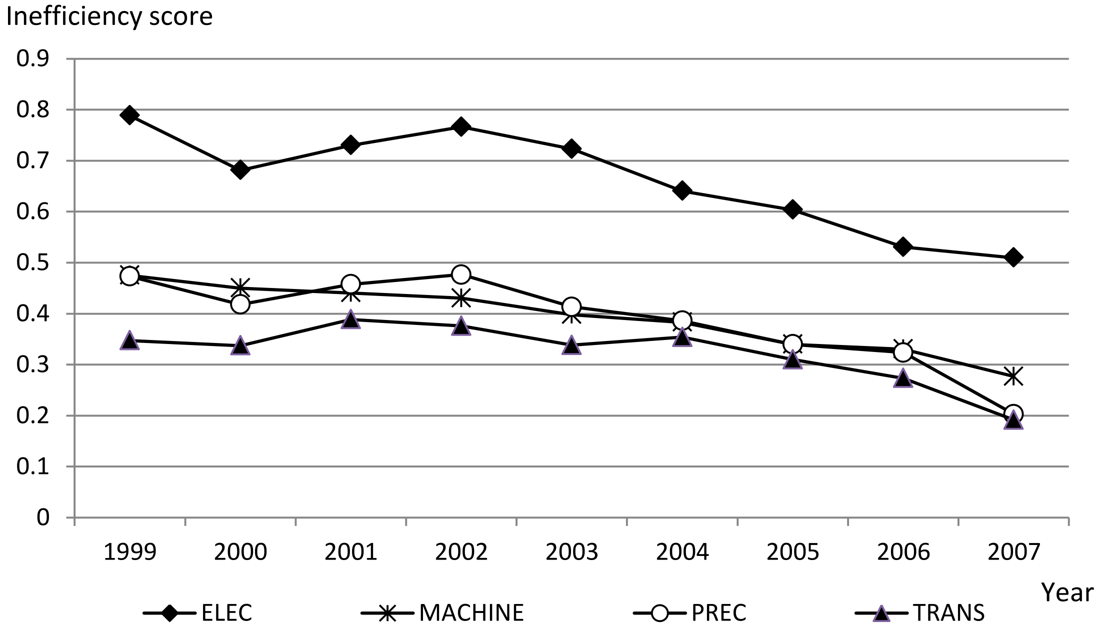

Figure 2. Inefficiency score change of U.S. processing and assembly industry from 1999 to 2007

Source: Author created

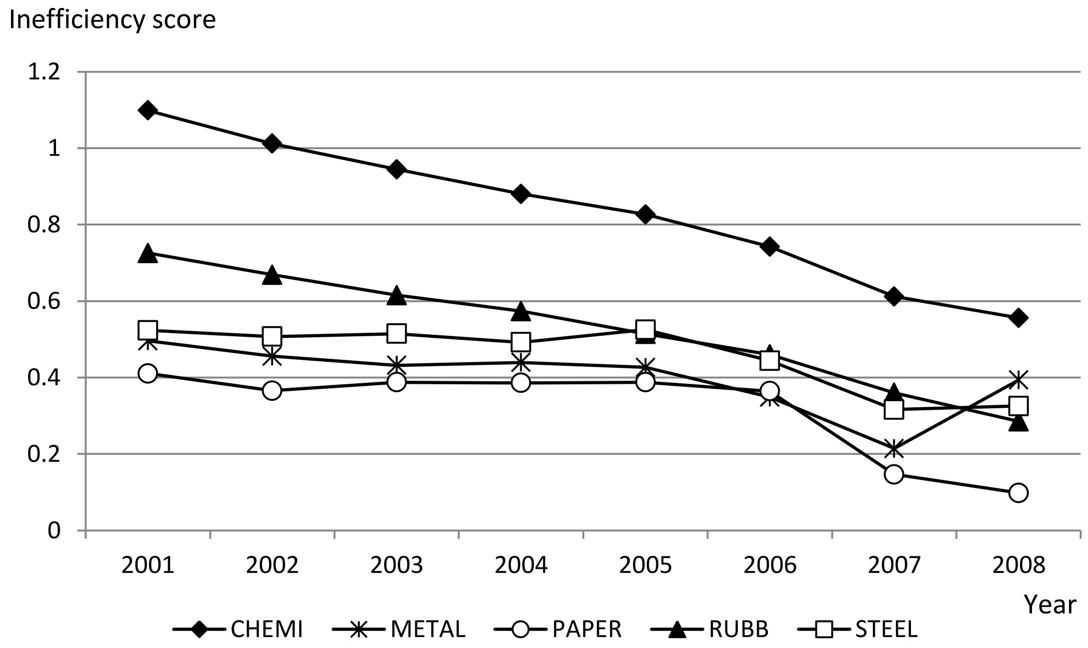

Figure 3. Inefficiency score change of Japanese basic material industry from 1999 to 2007

Source: Author created

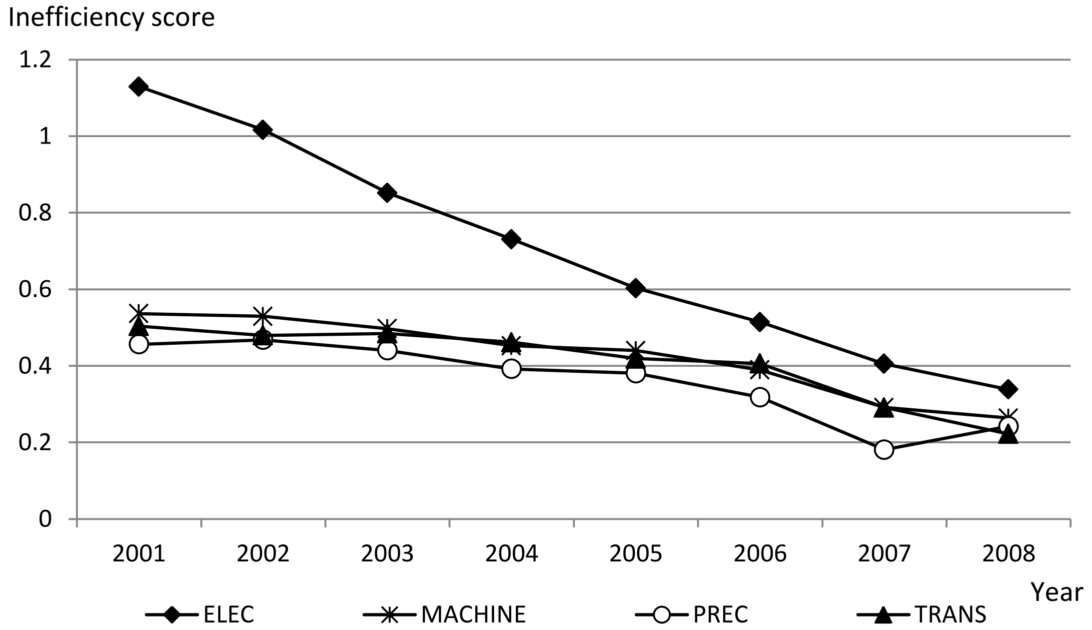

Figure 4. Inefficiency score change of Japanese processing and assembly industry from 1999 to 2007 Source: Author created