Corporate environmental and economic performances of Japanese manufacturing firms: Empirical study for sustainable development

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Abstract

This study examines the relationships between environmental performance and economic performance in Japanese manufacturing firms. The environmental performance indicators include CO_2 emissions and the aggregate toxic risk associated with chemical emissions relative to sales. Return on assets (ROA) is used as an indicator of economic performance. We demonstrate that there is a significant, inverted U-shaped relationship between ROA and environmental performance calculated by aggregated toxic risk. We also find that the environmental performance increases ROA through both returns on sales and capital turnover improvement. However, we observe a significant, positive relationship between financial performance and environmental performance based on CO_2 emissions. These findings may provide evidence for the consequences of environmental firm behavior and sustainable development.

Keywords: Corporate environmental management, Environmental efficiency, CO_2 emissions, Toxic chemical substances, Japanese manufacturing firm, Sustainable development

1. Introduction and background

According to Porter (1991) and Porter and Linde (1995), properly designed environmental regulations can encourage technological development, promote firms' environmental activities and enhance environmental performance. Hence, it is believed that technological development and improved resource productivity can increase firms' competitiveness and enhance their overall economic performance. Many studies have been conducted to test this hypothesis, called the "Porter hypothesis" (see Ambec and Lanoie, 2008).

Many previous studies of the Porter hypothesis apply econometric approaches using linear functions (e.g., Al-Tuwaijri *et al.*, 2004; Nakao *et al.*, 2007; Iwata and Okada, 2011). These studies focus on the sign (positive or negative) of the relationship between environmental and economic performance. However, a positive linear relationship is not always fit into the relationship between environmental and economic performance (Hahn *et al.*, 2010). This is because pollution abatement requires additional investments and payments for nonproductive activity, whereas the economic benefit from pollution abatement activity is limited. Additionally, cost and economic benefit from pollution abatement are different among type of pollution because abatement technology and required equipment differ (e.g. recyclable or not). In the production process, a firm can gain economic benefits from recycling and intermediate material saving. However, these effects are usually smaller than the costs to manufacturing firms for pollution abatement (Jasch, 2006). Additionally, consumer preferences are still not significantly related to the environmental burden through the production process, but rather through product performance (Hibiki and Managi, 2010). Therefore, an environmentally friendly corporate image has a weak influence on the market competitiveness of products. Based on these arguments, the improvement of environmental performance possibly does not always generate economic profit.

While, many case studies in the business and corporate management fields support the Porter hypothesis (e.g., Steger, 2004; Claver *et al.*, 2007; Crotty and Smith, 2008; Testa *et al.*, 2012). Thus, some firms have successfully balanced environmental and economic performances. These results show that the economic benefit is not always lower than the pollution abatement cost.

The cost of corporate environmental management (hereafter, CEM) for firms is generally on the rise, although it is difficult to define and measure this cost because CEM includes a wide range of business activities in addition to compliance with environmental regulations. Moreover, the benefits or returns from CEM are not only expanding but also are often invisible. To enhance our understanding of the costs and benefits of CEM, this study examines the relationship between the environmental performance and economic performance of Japanese manufacturing firms.

2. Research framework and hypotheses

2.1 Research framework

Wagner *et al.* (2002) present a theoretical model of the relationship between the environmental and economic performance of firms. This model compares two different views: the "traditionalist" and the "revisionist". Based on the Wagner *et al.* (2002), we develop our research framework focusing three hypothetical relationships between environmental and economic performance (see Figure 1). The horizontal axis of Figure 1 represents environmental performance, and the left to right direction on the x-axis represents improvement in environmental performance. Each hypothetical relationship represents changes in economic performance if environmental performance is improved.

The former view ((A) in Figure 1: Traditionalist) suggests that environmental management is merely a cost incurred for environmental protection as economic performance declines (Walley and Whitehead, 1994). Because environmental protection requires additional costs and investments in a nonproductive sector that is not directly related to financial performance, this additional investment reduces firms' market competitiveness. Therefore, traditionalists point out there is a trade-off relationship between environmental performance and economic performance.

In contrast, the latter view ((B), (C), and (D) in Figure 1: Revisionist) follows Porter's hypothesis (Porter, 1991; Porter and Linde, 1995), suggesting that strengthening environmental performance is positively correlated with economic performance in some areas. Revisionists point out that pollution abatement costs and expenditure can be considered an investment in the innovation of new environmental technology that decreases abatement costs. Furthermore, revisionists explicitly consider the effects of human resources and knowledge that are accumulated by undertaking pollution abatement in daily production process, which are not specifically included in the traditionalist framework. The revisionists' point of view can be divided into three hypotheses. First, economic performance increases when environmental performance improves ((B) in Figure 1). Second, the relationship between environmental performance and economic performance is a U-shape ((C) in Figure 1). Finally, the relationship between environmental performance and economic performance is an inverted U-shape ((D) in Figure 1).

Here, we define the environmental activity of manufacturing firms as efforts and treatments aimed at conserving resources and reducing the environmental burden. Environmental activity can be divided into two major approaches. One is the end-of-pipe (EOP) approach[1], and the other is the cleaner production (CP) approach[2] (Frondel *et al.*, 2007). Under this clarification, traditionalist focuses on the EOP treatment, while revisionist emphasizes CP approach.

First viewpoint ((B) in Figure 1) focus on the economic benefit from CP approach. In this idea, environmental burden represents inefficient intermediate use in production process. Based on Zeng *et al.* (2010), manufacturing firms can save on intermediate material and labor due to an improved production process, which contributes cost reduction. Thus, increase environmental performance can be understood that improvement of resource use efficiency that strengthens the market competitiveness.

Second viewpoint ((C) in Figure 1) is based on the following idea. Under environmental regulations, firms need to pay a pollution abatement cost. Meanwhile, firms may benefit from environmental activity such as material reuse and recycling (Palmer *et al.*, 1995; King and Lenox, 2001). Environmentally proactive firms achieve especial benefits from

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[1] The EOP approach is based on pollution removal using so-called “filters” in smokestacks or drains. Major EOP technologies include desulfurization and wastewater treatment. However, EOP technology has several defects. EOP treatments cause secondary environmental pollution problems such as the generation of sludge waste through wastewater treatments, the need for substantial investment in equipment and expensive running costs. EOP treatments do not contribute directly to improving productivity. Because firms perceive the costs of EOP treatments as additional expenditure for nonproductive activity, they do not usually have strong incentives for pollution abatement through the EOP approach.

[2] The CP approach is defined as “the continuous application of an integrated preventive environmental strategy applied to processes, products, and services to increase overall efficiency, and reduce risks to humans and the environment” (UNEP, 2006). A major CP approach is eco-design, in which the product design considers the environmental impacts of the product during its entire lifecycle. While the CP approach also requires investment in equipment, as does the EOP approach, running costs are not as expensive because the CP approach does not require filters and absorbent materials to remove pollutants (Kjaerheim, 2005).

environmental activities that outweigh the cost. Furthermore, we point out the possibility to have positive relationship between environment and economic performance by human resource development. Inducing CP approach make manufacturing firm increase economic performance. However, manufacturing firm needs to cultivate pollution abatement experience and knowledge to induce CP approach. In many case, manufacturing firms learn more efficient pollution abatement approach by doing daily environmentally activity (Remmen and Lorentzen, 2000). While, firm needs to use EOP approach for pollution abatement to comply strictly with environmental regulations before firm builds up enough capacity to apply CP approach. In this period, economic performance goes down temporarily with emission reduction by EOP approach. However, firm gain the enough human resource and capacity to induce CP approach, economic performance goes up with environmental performance improvement. To keep treating environmental burden, employee's capacity and know-how will be accumulated, which makes more efficient environmental treatment activity that increase economic performance.

Third viewpoint ((D) in Figure 1) can be explain as follows. Marginal abatement cost of pollution is higher than the marginal benefit from pollution abatement when the firm's environmental performance is high. This is because firms can select from several cost-effective equipment options for environmental management when environmental performance is low. After improvements of environmental performance due to the introduction of several cost-effective approaches, a firm needs to obtain cost-ineffective equipment if it hopes to improve environmental performance by introducing new equipment. Thus, economic performance has a negative relationship with environmental performance. In this period, the firm does not have strong incentives to improve environmental performance by incurring costs if it has already met the environmental standard. However, the firm needs to reduce environmental pollution beyond the environmental standard if a client firm demands it. This requirement from the client firm provides an incentive for firms in the supply chain to promote environmental management[3].

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[3] Many Japanese manufacturing firms set a target and report the environmental performance of the consolidated entity or product life cycle in their environmental reports. To meet the environmental target, a manufacturing firm tries to reduce the environmental burden in the product supply chain. The Restriction of Hazardous Substances (RoHS) law was adopted in July 2006 in the European market. Since then, six substances have been banned from new electrical and electronic products in the European market: lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls and polybrominated diphenyl ethers. This strict environmental regulation in European

<Figure 1 about here>

Empirical studies have attempted to assess whether a balanced relationship can exist between environmental and economic performance (Aragón-Correa *et al*., 2008; Darnall *et al*., 2008; Iraldo *et al*., 2009; Clarkson *et al*., 2011;). Several scholars argue that no positive relationship exists between economic and environmental performance (Walley and Whitehead, 1994; Böhringer *et al*., 2012) or that benefits may occur only under specific conditions (Palmer *et al*., 1995; Rugman and Verbeke, 1998; Henri and Journeault, 2010; Schaltegger and Wagner, 2011). Multiple regression analysis has been used to examine this relationship in the United States (Hart and Ahuja, 1996; Konar and Cohen, 2001; Al-Tuwaijri *et al*., 2004), the UK (Thomas, 2001), and Europe (Wagner *et al*., 2002).

Several studies focus on Japanese firms. Nakao *et al*. (2007) analyze the relationship between environmental performance and financial performance in the context of Japanese corporations. They use environmental performance indices based on the *Nikkei Environmental Management Survey* and apply linear functional form to estimate. Data sample is 121 Japanese manufacturing firms and time periods is 2002 and 2003 year. They find Japanese firm's environmental performance has a positive impact on its financial performance.

Hibiki and Managi (2010) clarify the relationship between toxic chemical risk and economic performance for Japanese manufacturing firms. Data sample is 402 Japanese manufacturing firms and time periods is 2003 and 2004 year. Iwata and Okada (2011) examines the effects of environmental performance on financial performance using the data of 268 Japanese manufacturing firms from 2004 to 2008 by applying linear functional form. They use greenhouse gas and waste emissions as environmental performance and find the different effects of each environmental performance on financial performance.

Nishitani *et al*. (2011) analyzes whether the reduction of toxic chemical substances emissions improves a firm's economic performance through the increase in sales to environmentally conscious customers and the cost reductions associated with the improvement in productivity. They use panel data for 426 Japanese manufacturing firms over the period 2002–2008 and apply production function with logarithmic form. The findings indicate that

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market causes manufacturing firms in Japan to promote the management of toxic chemical substances in all of the processes of the product supply chain.

firms that have reduced their pollution emissions can increase their economic performance through the increase in demand for their products and an improvement in productivity. Nishitani and Kokubu (2011) uses the data on 641 Japanese manufacturing firms in the period from 2006 to 2008. They find that firms with strong market discipline imposed by stockholders/investors are more likely to reduce GHG emissions and, consequently, firms that reduce more GHG emissions are more likely to enhance firm value.

However, these studies do not consider the quadratic relationship between environmental and economic performance. Additionally, there are little studies use multiple type of environmental pollution data to represent environmental performance. While, many types of environmental pollution are caused by manufacturing firms. It is thus important to consider several types of environmental pollution to understand properly the relationship between corporate financial performance and CEM. Additionally, previous studies have used data on the amounts of chemical substances emitted without considering the toxicities of the chemical substances. However, manufacturing firms manage their emissions of chemical substances with a focus on the toxicity to humans and the ecosystem form risk management of pollution accident (Fujii *et al*., 2011). Thus, we attempt to include the toxicities of chemical substance emissions in our analysis.

2.2 Objective and hypotheses

The objective of this study is to clarify the relationship between environmental and economic performance using both linear and quadratic functions. Given the availability of the data and Japan’s rich experience with CEM, studies of Japanese manufacturing firms that directly analyze environmental and economic performance using multiple real environmental pollution data sources are particularly relevant.

We focus on the three economic performance indicators to examine the causal relationship between environmental and economic performance in detail. In general, CEM contributes to economic performance though (1) the cost saving effect and (2) the productivity improvement effect (Grolleau *et al*., 2012). The former effect includes reductions in intermediate material costs, energy input costs, and pollution abatement costs as a result of pollution-prevention activity. The latter effect is achieved through improved capacity utilization and increased sales from environmentally product design. To consider these two different effects, we use return on sales (ROS)[4] to capture the cost saving effect and capital turnover (CT)[5] to capture the capital productivity improvement effect in our research. Additionally, we use the return on assets (ROA) indicator to evaluate economic performance by considering both the cost saving effect and the productivity improvement effect (overall economic performance effect).

As a side note, environmental performance can be measured by various pollutants. Additionally, technology, cost, and equipment for pollution abatement differ according to pollutant. Therefore, this study focused on two environmental pollutants with different characteristics. The first is toxic chemical substances that cause local environmental pollution problems, directly affecting human health and ecosystems in the short term. Pollution abatement methods can be applied using both the EOP approach and the CP approach.

The second is CO_2 emissions, which cause global environmental problems and indirectly affect human health and ecosystems in the long term. Attempts have been made to reduce CO_2 emissions by adopting the CP approach, which is fossil fuel energy conservation. Today, new abatement technologies to reduce CO_2 emissions by the EOP approach have been invented, but these approaches remain difficult and are too expensive for private firms. To focus on the characteristics, effects and available abatement technology of these two pollutants, we clarify how each aspect of environmental performance affects financial performance. To analyze this relationship, the discussion in this section focuses primarily on the development of three research hypotheses that are (a) *cost saving effect*, (b) *capital productivity improvement*, and (c) *overall economic performance effect*.

(a) *Cost saving effect*

Reducing CO_2 emissions is mainly achieved by the manufacturing firm through fossil fuel energy conservation, which saves energy costs if sale is constant. Thus, decreasing CO_2 emissions reduces production costs, and this contributes to increased profitability. Therefore,

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[4] ROS is defined as profit per sale, which represents the profitability of a firm. Basically, profit is calculated by determining the value of sales minus costs, including intermediate material costs and pollution abatement costs. Therefore, we consider ROS can capture the cost saving effect of CEM.

[5] CT is defined as sales per asset, which represents the capital productivity of firm. CT does not directly reflect the cost saving effect, but it can capture the efficiency of investments to increase sales. Hence, we believe that CT can depict how investment, including pollution abatement, contributes to increased sales.

we hypothesize that the relationship between corporate profitability and environmental performance measured by CO_2 emissions is positive, as shown in (B) in Figure 1.

While, the abatement costs of toxic chemical substances differ for each approach. The CP approach is inexpensive. However, it is impossible for manufacturing firms to remove all environmental pollution by only applying the CP approach. In short, firms need to apply both the EOP and CP approaches in a balanced way to achieve high environmental standards and increase firm's profitability (Frondel *et al*., 2007). Thus, if a manufacturing firm reduces its toxic chemical substances emissions too drastically by applying an additional EOP approach, the environmental performance measured by toxic chemical substances emissions improvement reduces corporate profitability.

Therefore, we hypothesize that the relationship between corporate profitability and environmental performance measured by toxic chemical substances emissions is a quadratic function with a convex upward shape as indicated by (D) in Figure 1.

Hypothesis 1. The relationship between profitability and environmental performance measured by CO_2 emissions is positive. While, the relationship between profitability and environmental performance measured by toxic chemical substances emissions is a quadratic function with a upward convex (from the existing optimal point).

(b) *Capital productivity improvement*

If a manufacturing firm reduces CO_2 emissions by introducing new energy-efficient production equipment, capital productivity falls temporarily (Fujii *et al*., 2010). However, low carbon product has strong market competitiveness if preference of consumer and market shift to environmental friendly product. In this case, reduction of CO_2 emissions affects to increase capital productivity gradually. While, Pedersen and Neergaard (2005) pointed out that the effect of green purchasing and green labeling is limited. Thus, we consider two possibilities that CO_2 reduction affect to decrease capital productivity or to increase capital productivity gradually.

Meanwhile, inducing new equipment for toxic chemical substances abatement is an additional investment and is a nonproductive activity. However, importance of toxic chemical substances managements gets stronger due to strict environmental standard targeting on entire product supply chain[6]. Thus, these strict environmental standards make the market competitiveness of firms with proactive toxic chemical substances management increase. Meanwhile, both CP and EOP approach for toxic chemical substances management are required new investment for pollution abatement, while that investment does not directly increase sales because consumer and market preferences are not affected by the information of toxic chemical substances emission by firm (Hibiki and Managi, 2010). These evidences imply that excess toxic chemical substances management possibly decline capital productivity.

Thus, we hypothesize that the relationship between capital productivity and environmental performance measured by toxic chemical substances emissions is negative as indicated by (A) in Figure 1 or inverted U-shape relationship as indicated by (D) in Figure 1.

Hypothesis 2. The relationship between capital productivity and environmental performance measured by CO_2 emissions is quadratic function with a downward convex. While, the relationship between capital productivity and environmental performance measured by toxic chemical substances emissions is a negative or quadratic function with a upward convex (from the existing optimal point).

(c) *Overall economic performance*

We define overall economic performance as financial performance considering both profitability and capital productivity. Based on the hypothesis 1 and hypothesis 2, investment for CO_2 emissions reduction contributes energy use saving, which increases ROS. However, there is not clear relationship that CO_2 emissions reduction increase market competitiveness. Thus, we predict that the increase of environmental performance measured by CO_2 emission

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[6] For example, (1) the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS); (2) the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH); and (3) the End-of-Life Vehicles Directive (ELV). The REACH directive was adopted in 2006 in Europe and required firms that export to the European market to be more proactive in controlling toxic chemical substances. In 2018, the REACH directive plans to cover 30,000 chemical substances in firms treating more than 1 ton per year. Under the RoHS and ELV directives, all electric and vehicle products with a level of toxic chemicals above a certain threshold cannot be sold in the European market. Additionally, Japan's *marking for the presence of specific chemical substances for electrical and electronic equipment* (J-MOSS) was enforced in July 2006. It is an eco-labeling system that targets six toxic chemical substances (the same as those in the RoHS restriction) and seven electrical and electronic products, and it was enforced in tandem with the RoHS restriction.

increase overall economic performance through the corporate profitability improvement.

While, we consider that environmental performance measured by toxic chemical substances emissions have inverted U-shape relationship with two economic performances (profitability and capital productivity) in hypothesis 1 and 2. Then, we assume inverted U-shape relationship between overall economic performance and environmental performance measured by toxic chemical substances emissions.

Hypothesis 3. The relationship between overall economic performance and environmental performance measured by CO_2 emissions is positive relationship. While, the relationship between overall economic performance and environmental performance measured by toxic chemical substances emissions is a quadratic function with a upward convex (from the existing optimal point).

3. Methodology

In this paper, economic performance denotes the economic benefits generated by firms' activities, and environmental performance is defined as the result of CEM. Based on these definitions, we establish return on sales (ROA) as our economic performance (Econ) indicator and environmental efficiency (EE) as our environmental performance indicator. EE is defined as desirable output (e.g. sales, production) per environmental burden. In other words, EE is the inverted score of environmental pollution per unit of production, which represents the production scale-adjusted environmental pollution. Therefore, we know that EE is highly dependent on the capacity for CEM.

ROA indicates profitability of a firm relative to its total assets. ROA is a generally accepted measure of firm financial performance that has been used as an economic performance variable in many previous studies (Russo and Fouts, 1997). The definition of ROA is profits divided by assets. By this definition, ROA can be decomposed using equation (1).

$$\text{ROA} = \text{Profit/Asset} = \text{Profits/Sales} \times \text{Sales/Assets} \tag{1}$$

This means that improvements in ROA can be caused by an increase in profits divided by sales, which is called return on sales (ROS), or by an increase in sales divided by assets, which is called capital turnover (CT). ROS indicates the profitability of corporate activity, and CT represents the capital productivity of firms. Therefore, changes in ROA can be considered according to changes in ROS or changes in CT. In this paper, we seek to clarify independently how EE affects ROA, ROS and CT.

On the one hand, we examine the relationship between Econ and EE, on the other hand, we consider the following two specifications, shown in equations (2) and (3). The relationships are assumed to be linear and quadratic in Models 1 and 2, respectively.

$$\text{Model 1} \quad Econ_{it} = \alpha_1 \cdot EE_{it-1} + \mathbf{X}_{it}\boldsymbol{\alpha}_2 + \eta_i + \mu_t + \varepsilon_{it} \tag{2}$$

$$\text{Model 2} \quad Econ_{it} = \beta_1 \cdot EE_{it-1} + \beta_2 \cdot EE_{it-1}^2 + \mathbf{X}_{it}\boldsymbol{\beta}_3 + \eta_i + \mu_t + \varepsilon_{it} \tag{3}$$

Let the i th firm's economic performance in year t be Econ_{it} with ROA, ROS and CT. EE_{it-1} is the i th firm's environmental efficiency in year $t-1$. Two variables comprise EE, namely, sales per CO_2 emissions (EE_{CO2}) and sales per toxic release (EE_{toxic}). There are, therefore, six combinations of Econ and EE in our model. To capture firm characteristics influencing Econ, vector $\mathbf{X}$ is incorporated into the models. η and μ are unobserved firm- and time-specific fixed effects, respectively. ε is an idiosyncratic error term. α and β are the estimated coefficients.

For vector $\mathbf{X}$, which represents firm characteristics, we use four variables: the number of employees (Emp), research and development expenditure relative to sales (R&D), capital investment relative to sales (Invest) and capital intensity (Intensity). In selecting these control variables and setting expectations for each variable, we follow Capon *et al.* (1990). Emp is used as a proxy for firm size[7]. We use R&D to capture the firm's technological knowledge level[8].

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[7] We use number of employees to control firm scale effect in our model. Because firm scale affect the productive efficiency in manufacturing firms. According to Halkos and Tzeremes (2005), large firms could be more efficient in production because they could use more specialized inputs, better coordinate their resources, etc. Meanwhile, small firms could be more efficient because they have flexible, non-hierarchical structures, and do not usually suffer from the so-called agency problem.

[8] We use $R\&D_{it-1}$ rather than $R\&D_{it}$ as an independent variable because there is time lag between R&D investment and the economic performance improvement (Osawa and Yamasaki, 2005; Ogawa, 2007). Thus, we use R&D variable with one time year lag.

Invest stands for the firm's level of production equipment technology[9]. Intensity indicates whether the firm is labor intensive or capital intensive.[10]

We use EE_{it-1} rather than EE_{it} as an independent variable to avoid an endogeneity problem, similar to Wagner (2010). Additionally, this variable select is useful for adjusting real information disclosure system in Japan because Japanese Ministry of the Environment provided both CO_2 and toxic chemical emissions information that is published approximately one year after the ministry collects information.

4. Data

We use CO_2 emissions and toxic chemical substances emissions to calculate EE. The CO_2 emissions data were obtained from the GHG Emission Data report obtained through the Mandatory Greenhouse Gas Accounting and Reporting System of the Ministry of the Environment[11]. Because this system discloses CO_2 emissions for individual firms from 2006 to 2008, three years of data are available. As another measure of environmental performance, toxic chemical emissions information for each firm was obtained from the Pollutant Release and Transfer Register (PRTR) system report published by the Ministry of the Environment[12]. Toxic emissions data are available for the period between 2001 and 2008. Because manufacturing firms emit many types of toxic chemical substances, we use an integrated risk

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[9] We use Invest_{it-1} rather than Invest_{it} as an independent variable because there is time lag between capital investment and the economic performance improvement (Nagahata and Sekine, 2005). Thus, we use capital investment variable with one time year lag.

[10] We use capital intensity (assets/employees) to control how firm depend on the capital equipment. In general, high capital intensity firm has low CT score due to high dependency of capital equipment. While, high capital intensity firms tend to pay lower labor cost relative to labor intensive firms. Thus, high capital intensive firm tend to have high ROS score. To control these characteristics of capital-labor ratio, we apply capital intensity variables in our model.

[11] Under this system, firms that have more than 21 employees and GHG emission is more than 3,000 ton-CO_2, or energy consumption of all facilities is bigger than 1,500 kl of oil equivalent must annually report the quantities they use to the central government.

[12] Japan has enforced the pollution release and transfer register (PRTR) since 2001. Under this system, facilities that have more than 21 employees and produce or use chemicals on a list of 354 substances specified by law must annually report the quantities they use to the central government.

score calculated from toxic chemical emissions and toxicity weight according to the United State Environmental Protection Agency (EPA)[13]. There are two reasons why we use an integrated risk score. First, firms manage chemical substances to reduce overall risk[14]. Second, it is common for the emissions of some chemical substances to increase and others to decrease because firms substitute one chemical input for another to reduce the toxicity impact[15]. For these reasons, we use integrated risk score calculations based on information regarding 134 toxic chemical substances to represent emission amounts[16].

To define EE, we use sales to indicate economic value in this paper because sales reflect overall product value, and sales are not affected by the cost reductions that may occur due to labor restructuring and changes in wages that do not directly relate to CEM. In this case, EE is defined by the ratio scale between sales and environmental pollution. If the production scale declines, environmental pollution will decrease, and sales will fall. As a result, EE is not greatly affected by the production scale change effect. Thus, the EE score controls for the production scale change effect caused by business cycles. In this study, we use ROA as an economic performance indicator that is the adjusted production scale. To consider conformity to economic performance, we select the EE indicator as a performance result of CEM.

The sample size is 758 in CO_2 data set (sample A) and 2,498 in toxic chemical emissions data set (sample B)[17]. All sample firms are listed firms on the Tokyo stock exchange market. All financial data variables are from the Nikkei Economic Electronic Database Systems. Two data sets are constructed for firms in the manufacturing sector, as summarized in Table 1.

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[13] Toxic coefficient scores come from the toxicity weighting spreadsheet v2.3.0, published by the U.S. EPA.

[14] For instance, the Japanese Chemical Industry Association (JCIA) convenes many workshops and seminars to disseminate knowledge to JCIA member firms on how to reduce the total toxicity of emitted chemical substances. The JCIA consists of 180 industrial chemical firms and 75 business associations.

[15] The main toxic chemical substitutions are adapted from toluene and xylene to butyl acetate and ethyl acetate.

[16] There are 354 chemical substances in the PRTR published by the Ministry of the Environment in Japan. The toxic weight provided by the U.S. EPA covers only 134 chemical substances in the PRTR data in Japan. Therefore, we consider that 134 chemicals, which are targeted for toxic chemical management in both the U.S. and Japan, are recognized high priority substances.

[17] A limitation of our study is the difficulty obtaining consolidated firm data. Some of the small consolidated subsidiaries do not report their emissions data because they do not have a duty to report their CO_2 and toxic chemical substance emissions to the government. This is because the thresholds of the reporting system include firm scale (number of employees). Because of the difficulty of data accessibility from small firms, we could not obtain all the environmental data for consolidated firms.

We describe the distribution of sample firm by type of industries in Table 2. The descriptive statistics in our data set are presented in Table 3[18]. All financial data is deflated as 2005 price.

<Table 1 about here>

<Table 2 about here>

<Table 3 about here>

5. Results

5-1. Economic performance vs environmental performance measured by CO_2 emissions

Table 4 shows the results when the environmental performance indicator is EE measured by sales per CO_2 emissions (EE_{CO_2}). In Model 1, the single power of EE_{CO_2} has a significant and positive effect on ROA. However, neither the single power nor squared term of EE_{CO_2} has significant effects in Model 2. These findings imply that the relationship between ROA and EE_{CO_2} is linear and positive. ROA and EE_{CO_2} are compatible, and their relationship remains steady.

In considering ROS and CT, we find that EE_{CO_2} has a monotonically positive effect on ROS because squared term of EE_{CO2} is significantly positive and single power of EE_{CO2} is not statistically significant. While, there is no significant effect on CT. Based on these results, we can conclude that EE_{CO_2} affects ROA through ROS because both ROA and ROS have positive relationship with EE_{CO2}, and the relationship between EE_{CO_2} and CT is not statistically significant. These results can be interpreted using the following mechanisms. ROS shows the profitability of firms, with profits defined as the difference between sales and cost. A higher ROS implies lower costs relative to revenue. CO_2 emissions from manufacturing firms are

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[18] Mean value of ROA in our dataset is 0.456% in sample A and 1.780% in sample B. Based on Meric et al. (2008), average ROA score of Japanese firms from 2001 to 2005 is 2.40%, which is close to our data. Our dataset is included data in 2008 year which is strongly affected by financial crisis. Especially, average ROA score in sample A is strongly affected because time period of sample A is three years, which are 2006, 2007, and 2008. Thus, we consider mean value of ROA score in our revised dataset is not abnormal.

produced mainly through the consumption of energy. Therefore, firms with lower CO_2 emissions relative to sales have achieved more energy-efficient production processes. The efficiency of their production systems decreases energy costs and positively affects ROS.

There are two main approaches to reducing CO_2 emissions in manufacturing firms[19]. The first approach is to introduce more energy-efficient production equipment and switch from fossil fuels to forms of energy with lower carbon intensity. This approach requires additional investment and costs. Second approach is to improve the production process and employee efforts to save energy, which requires better corporate management, including better employee education and excellent leadership[20]. Later approach can be available by a learning curve effect, which occurs when a firm develops more efficient pollution abatement techniques by experimenting with environmentally friendly activities (Bramoulléa and Olson, 2005). Employee effort and ideas are necessary, but such initiatives do not require a significant capital investment or additional cost (Remmen and Lorentzen, 2000).Employee efforts can help many Japanese manufacturing firms successfully reduce CO_2 emissions without significant additional investment (Stone, 2000).

Here, we introduce Ricoh's corporate activity report as a case study to illustrate the successful adoption of cleaner production technology without large investment. Ricoh has successfully reduced CO_2 emissions and energy use by introducing cleaner production technology, which entailed shifting from automation technology equipment to employees' activity-oriented technology. Ricoh developed a new manufacturing line consisting of carts chained together in a single line. This new system only needs a single 0.4 kW motor to run while conventional lines (conveyor belts) need one in the 6 kW range. By the introduction of this production process, CO_2 emissions were reduced from 7.7 to 0.1 tonnes of CO_2 per year, electricity use was reduced from 90 kWh per day to 1 kWh per day, investment was decreased from 20 to 0.28 million yen per year, and maintenance fees cut from 2.24 million yen per year to 0 yen per year.

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[19] Carbon capture and storage (CCS) is another option, but this approach is not considered here.

[20] For example, Panasonic has established a corporate CO_2 emissions reduction promotion committee to manage its progress toward the achievement of its target on a monthly basis. Through this committee, the firm facilitates (1) the visualization of energy consumption, (2) energy conservation diagnoses by an expert team, (3) innovations in production processes, and (4) group-wide sharing of examples of reductions that have taken place (Panasonic group, 'eco ideas' Report 2010).

However, we do not observed significant relationship between CT and EE_{CO2}. We point out two reasons about this result. First, introducing energy-saving equipment through significant capital investment decreases firm capital productivity in the short term (see Fujii *et al*., 2010). Second, many buyer firms in Japan tend to purchase products that have production processes with low carbon emissions, hoping to improve their life-cycle assessments and green supply chain management. Therefore, energy-efficient manufacturing firms obtain a competitive position in the market with buyers that are proactive about green purchasing. We consider these positive and negative effects are canceled each other out in the relationship between CT and EE_{CO2}, which is one reason we can not observed significant relationship in our analysis. Based on this result, we conclude our results support hypothesis 1 and 3 about environmental performance measured by CO_2 emissions.

<Table 4 about here>

5-2. Economic performance vs environmental performance measured by toxic risk score

Table 5 shows the results achieved using the sales per toxic risk score (EE_{toxic}) as the independent variable. The single power of EE_{toxic} does not have statistically significant effect on ROA in Model 1. However, if the square term of EE_{toxic} is included (as in Model 2), an inverted U-shaped relationship emerges between ROA and EE_{toxic}. Additionally, the turning point in this inverted U-shaped curve is in the first quadrant[21] because the single power of EE_{toxic} positively affects ROA. From the comparison of tables 4 and 5, we find EE_{toxic} and EE_{CO2} have different effect on the ROA.

Here, we focus on the results for the model with dependent variables ROS and CT. EE_{toxic} has positive and linear relationship with ROS, and EE_{toxic} has inverted U-shape relationship with CT. This result indicates that EE_{toxic} increase ROA through improvement in both ROS and CT, and decrease ROA through CT decline. In a period when manufacturing firms can reduce toxic chemical substances emissions using CP, the increase in EE_{toxic} may positively affect ROS because of intermediate chemical material costs and abatement cost

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[21] First quadrant is located at the top right of the graph. There is the threshold of environmental performance which makes the relationship between economic performance and environmental performance change from positive to negative if turning point of inverted U-shape curve exists at the first quadrant.

reduction.

We introduce another Ricoh's corporate activity report as a case study to illustrate the successful adoption of cleaner production technology without a large investment. Ricoh has successfully reduced its emissions of toxic chemical substances and intermediate chemical inputs by improving the production process and product design with a new environmental strategy. In 2010, Ricoh successfully reduced the amount of toxic chemical substances used and emitted by 72.9% and 87.9%, respectively, compared to the fiscal 2000 level (Ricoh Corporation, 2011). This large reduction was primarily achieved through the development of improved product design using biomass resins and employee effort in the painting and washing process. Ricoh's environmental accounting finds 1.35 billion yen as the business area cost of pollution abatement and 2.21 billion yen as the benefit from energy saving and improved waste processing efficiency at the business site. This information demonstrates that appropriate pollution abatement generates corporate profitability.

While, we observed the inverted U-shape relationship between CT and EE_{toxic}, which represents growth of EE_{toxic} make increase CT until turning point. One interpretation of this result is that CP approach possibly decrease required investment for pollution abatement and production. As we explain using Ricoh's case study in previous section, innovative production process improvement make reduce firm's required investment for production. Thus, this investment saving affect increases CT. Another reason is that importance of green supply chain management gets stronger in both domestic and global market due to stricter environmental regulations such as RoHS and REACH district. Under these regulations focusing entire product lifecycle, products made by using small amount of toxic chemical substances have market competitiveness. Thus, positive relationship between EE_{toxic} and CT is exist.

However, this positive relationship is limited. Based on conclusions of Hibiki and Managi (2010), it appears that the Japanese market does not have a strong interest in the amounts of toxic substances that firms release or the associated risks. Because corporate toxic chemical substances management does not directly affect stakeholder or consumer preferences, EE_{toxic} is not related significantly to firm revenues.

From these results, inverted U-shape relationship between CT and EE_{toxic} can be explained as follows. Positive relationship is cause by investment saving effect and supply chain management requirement, while negative relationship after turning point is cause by capital productivity decline due to excess investment for pollution abatement. Based on this result, we conclude our results support hypothesis 2 and 3 about environmental performance measured by toxic chemical substances.

<Table 5 about here>

6. Conclusion

In this study, we examined the relationship between environmental performance and economic performance. Based on an empirical analysis of Japanese manufacturing firms, we find a significant, positive relationship between two financial performance indexes (overall economic performance and profitability) and environmental performance measured by CO_2 emissions. These results imply that firms improved their overall economic performance due to savings on intermediate energy costs. Furthermore, reduction of CO_2 emissions may not improve capital productivity in the short term.

This evidence includes new implications that environmentally friendly behavior for CO_2 reduction is worthwhile for firms seeking to improve their profitability but not their capital productivity. One interpretation of the results for capital productivity is the limited market preference for environmental friendliness.

However, market preferences in Japan have become more sensitive to corporate environmental management in recent years. For instance, Coca-Cola Limited (Japan) produced a new bottled water product called “ILOHAS” in bottles weighing only 12 grams, which is 40% less than the conventional product. This environmentally friendly product design was achieved by using plant-based material. This product innovation was designed to reduce material flows of production due to dematerialization and to save intermediate production costs. Additionally, this innovative bottle can be crushed easily, which reduces the volume of waste. This eco-friendly product design not only reduces production costs but also appeals to environmentally conscious consumers. By January 2011, ILOHAS had sold more than eight billion bottles since its release in 2009. This case study shows that environmentally friendly products have made gains in market competitiveness in Japan.

In addition, using the integrated chemical substance risk score, we have demonstrated that a significant, inverted U-shaped relationship between overall economic performance and environmental performance. We also find that environmental performance measured by integrated chemical substance risk score increases overall economic performance through improvements in both corporate profitability and capital productivity. This evidence implies that toxic chemical management is worthwhile for firms to increase their profitability and capital productivity in some areas.

Overall, in this study we clarified a turning point in the relationship between environmental efficiency measured by toxic risk and two economic performances (overall economic performance and capital productivity). Environmental policy at the national level needs to analyze the shift of inverted U-shape turning point to a more desirable direction. This is because it encourages more manufacturing firms to take on environmental initiatives to gain market competitiveness. Furthermore, there is no statistically significant relationship between capital productivity and environmental efficiency measured by CO_2 emissions. Another target for sustainable development is to have positive relationship between them. To achieve above goals, we make the following policy recommendations.

First, the government needs to promote industrial association to have workshops and seminars to educate firms about reducing CO_2 and toxic chemical substances emissions effectively without large investment. This progressive approach helps reactive firms and firms with low levels of environmental technology to reduce their emissions of pollutions without damaging their economic performance.

Second, financial support for investment on environmentally production equipment is important. Our research clarify that both CO_2 and toxic chemical substances management contribute to increase financial performance at the low environmental performance level. While, small and medium scale firms have difficulty to invest for environmental protection due to budget constraint even though they realize the positive effect between pollution reduction and economic performance. To solve this problem, loan with low interest rate for environmental protection investment is required.

Third, the construction of an environmental information disclosure system for the product life cycle (e.g. carbon footprint) is important to develop incentives for manufacturing firms to adopt proactive environmental management. This information disclosure system provides a new evaluation criterion for consumers to choose products. Additionally, government should carefully check the environmental information by enhance the monitoring system of pollution emissions and set more strict penalty for incorrect information report. Otherwise, firm has incentive to report incorrect information to have market competitiveness because environmental information has asymmetry property. Under such a scheme, manufacturing firms have an incentive to reduce environmental pollution because emission reductions reflect to the market competitiveness of products.

Further research should investigate the differences between the environmental efforts of firms in the service sectors in addition to the manufacturing sectors. Such an analysis could clarify this causal relationship in relation to industrial characteristics. Based on individual causal relationships, we can foster effective environmental policies that each firm needs to achieve sustainable development.

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	Sample A	Sample B
Observation	758	2,498
Time Period	2006–2008	2001–2008
Environmental Data	CO_2 emissions	Emissions form 134 toxic chemical substances
Data Source	*The GHG Emissions accounting, reporting and disclosure system (Ministry of Environment, Japan)*	*Pollutant Release and Transfer Registration (PRTR) (Ministry of Economy, Trade and Industry, Japan)*
Economic Data (ECON)	Return on assets (ROA), return on sales (ROS), capital turnover (CT)	
Data Source	*Nikkei Economic Electronic Database Systems*	
Control Variables	R&D expenditure relative to sales, capital investment relative to sales, capital intensity, number of employees	
Data Source	*Nikkei Economic Electronic Database Systems*	

Table 1. Description of Data Variables

	Sample A (CO_2 dataset)		Sample B (Toxic chemical substances dataset)	
Industry type	Number of samples	share	Number of samples	share
Rubber and Plastic	17	2.24%	63	2.52%
Paper and Pulp	18	2.37%	61	2.44%
Pharmaceutical	36	4.75%	78	3.12%
Chemicals and allied products	127	16.75%	565	22.62%
Industrial Machine	88	11.61%	369	14.77%
Automobile	60	7.92%	175	7.01%
Food	79	10.42%	131	5.24%
Precision instrument	22	2.90%	77	3.08%
Textile and apparels	28	3.69%	109	4.36%
Iron and Steel	40	5.28%	142	5.68%
Electric appliances	119	15.70%	348	13.93%
Electricity supply	14	1.85%	36	1.44%
Nonferrous metal	60	7.92%	212	8.49%
Transportation equipment	16	2.11%	55	2.20%
Glass and ceramics	34	4.49%	77	3.08%

Table 2. Sample Firm Distribution by Type of Industries

		Sample A		Sample B	
	Unit	Mean	S.D.	Mean	S.D.
ROA	%	0.456	6.084	1.780	4.546
ROS	%	0.244	11.354	1.919	9.152
CT	%	0.925	0.431	88.568	37.680
SALE	Million yen	2.27E+05	5.89E+05	1.72E+11	5.12E+11
CO_2	100kg-CO_2	2.75E+06	9.89E+06		
PRTR	gram			6.95E+09	2.24E+10
EE_{CO2}	Million yen/100kg-CO_2	0.454	0.729		
EE_{toxic}	Million yen/gram			1.665	48.178
R&D	Million yen	8,359	28,930	7951.24	33822.41
Invest	Million yen	11,423	38,789	9585.15	35442.01
Intensity	Billion yen/person	1.787	7.184	0.109	1.363
Emp	1,000 person	2.218	4.290	2.175	4.854
Obs		758		2,498	

Table 3. Summary of data variables

Dependent Variable	ROA		ROS		CT	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
$EE_{CO_2}{}_{-1}$	0.540 ***	0.621	-0.500	-12.655	-11.753	-31.683
$(EE_{CO_2})^2{}_{-1}$		-0.017		3.042 **		4.988
R&D/Sales	3.652	3.488	-524.396 **	-533.906 **	-296.104 ***	-311.697 ***
Invest/Sales	7.097 *	7.167 *	-46.631 **	-46.149 **	-22.709 *	-21.918 *
Emp	-0.013	-0.013	4.614	4.506	-7.390	-7.567
Assets/Emp	1.982	2.037	542.950 **	539.774 **	-400.283 ***	-405.492 ***
Cons	-2.274 ***	-2.300 ***	-22.262	-18.233	143.532 ***	150.139 ***
F value			14.700 ***	12.670 ***	11.180 ***	9.830 ***
Chi^2 value	179.57 ***	179.230 ***				
Model	random	random	fixed	fixed	fixed	fixed

Table 4. Results of analysis (EE_{CO_2} = Sales/CO_2 emissions)

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Dependent variable	ROA		ROS		CT	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
$EE_{toxic\,-1}$	0.002	0.013 *	0.003 *	0.015 *	0.007 *	0.049 ***
$(EE_{toxic})^2{}_{-1}$		-5.6E-6 *		-6.1E-6		-21.0E-6 ***
R&D/Sales	9.878 ***	9.943 ***	5.744	5.807	-64.857 **	-103.654 ***
Invest/Sales	1.300	1.298	-1.708	-1.715	-16.440 ***	-21.463 ***
Emp	0.029 **	0.029 **	0.025	0.025	0.026	0.067
Asset/Emp	-0.073	-0.073	-0.048	-0.048	0.049	0.040
Cons	-1.737 ***	-1.770 ***	-2.795 ***	-2.829 ***	93.540 ***	93.437 ***
F value					10.29 ***	
Chi^2 value	242.37 ***	260.57 ***	181.52 ***	219.96 ***		358.59 ***
Model	random	random	random	random	fixed	random

Table 5. Results of analysis (EE_{toxic} = Sales/Integrated risk score for PRTR emissions)

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

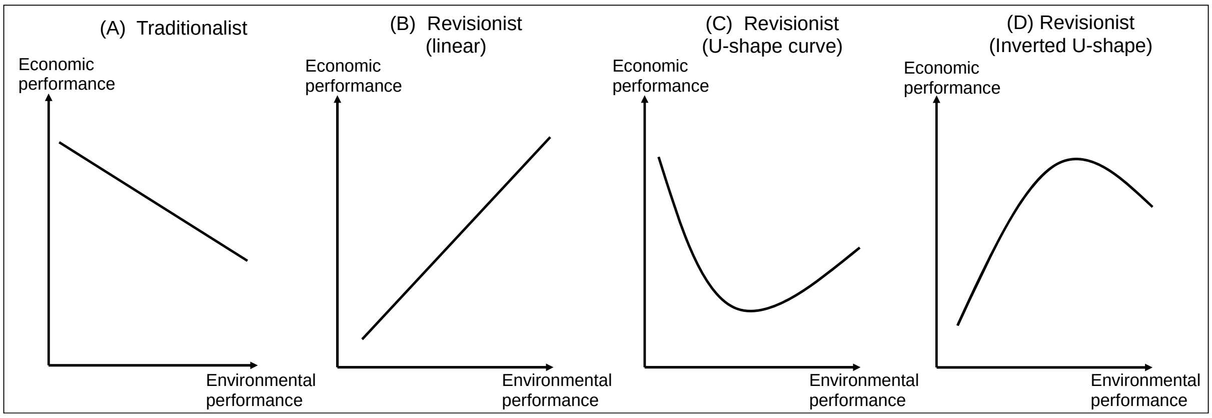

Figure 1. Relationship between economy and environment

Supplemental material.

List of 134 toxic chemical substances name.

CAS code	Chemical name
75-07-0	Acetaldehyde
94-75-7	Acetic acid
75-05－8	Acetonitrile
107-02-8	Acrolein
107-13-1	Acrylonitrile
15972-60-8	Alachlor
107-18-6	Allyl alcohol
107-05-1	Allyl chloride
33089-61-1	Amitraz
61-82-5	Amitrole
62-53-3	Aniline
90-04-0	Anisidine, o-
1332-21-4	Asbestos
1912-24-9	Atrazine
17804-35-2	Benomyl
71-43-2	Benzene
100-44-7	Benzyl chloride
75-25-2	Bromoform
74-83-9	Bromomethane
74-83-9	Bromomethane
106-99-0	Butadiene, 1,3-
63-25-2	Carbaryl
1563-66-2	Carbofuran
75-15-0	Carbon disulfide
84-74-2	Dibutyl phthalate
95-50-1	Dichlorobenzene, 1,2-
106-46-7	Dichlorobenzene, 1,4-
91-94-1	Dichlorobenzidine, 3,3'-
107-06-2	Dichloroethane, 1,2-
75-09-2	Dichloromethane
78-87-5	Dichloropropane, 1,2-
542-75-6	Dichloropropylene, 1,3-
62-73-7	Dichlorvos
115-32-2	Dicofol
60-51-5	Dimethoate
119-93-7	Dimethylbenzidine, 3,3'-
88-85-7	Dinitrobutyl phenol
51-28-5	Dinitrophenol, 2,4-
123-91-1	Dioxane, 1,4-
122-39-4	Diphenylamine
330-54-1	Diuron
106-89-8	Epichlorohydrin
110-80-5	Ethoxyethanol, 2-
140-88-5	Ethyl acrylate
100-41-4	Ethylbenzene
107-21-1	Ethylene glycol
75-21-8	Ethylene oxide
96-45-7	Ethylene thiourea
139-13-9	Nitrilotriacetic acid
98-95-3	Nitrobenzene
55-63-0	Nitroglycerin
100-02-7	Nitrophenol, 4-
86-30-6	Nitrosodiphenylamine, N-
1910-42-5	Paraquat dichloride
40487-42-1	Pendimethalin
87-86-5	Pentachlorophenol
52645-53-1	Permethrin
108-95-2	Phenol
95-54-5	Phenylenediamine, 1,2-
108-45-2	Phenylenediamine, 1,3-
106-50-3	Phenylenediamine, p-
85-44-9	Phthalic anhydride
88-89-1	Picric acid
1336-36-3	Polychlorinated biphenyls
41198-08-7	Profenofos
23950-58-5	Pronamide
709-98-8	Propanil
2312-35-8	Propargite
114-26-1	Propoxur
75-56-9	Propylene oxide
110-86-1	Pyridine
82-68-8	Quintozene

56-23-5	Carbon tetrachloride
120-80-9	Catechol
75-69-4	CFC-11
75-71-8	CFC-12
75-68-3	Chloro-1,1-difluoroethane, 1-
106-47-8	Chloroaniline, p-
108-90-7	Chlorobenzene
75-45-6	Chlorodifluoromethane
75-00-3	Chloroethane
67-66-3	Chloroform
74-87-3	Chloromethane
76-06-2	Chloropicrin
1897-45-6	Chlorothalonil
5598-13-0	Chlorpyrifos methyl
120-71-8	Cresidine, p-
1319-77-3	Cresol
533-74-4	Dazomet
1163-19-5	Decabromodiphenyl oxide
117-81-7	Di(2-ethylhexyl) phthalate
95-80-7	Diaminotoluene, 2,4-
333-41-5	Diazinon
13356-08-6	Fenbutatin oxide
55-38-9	Fenthion
51630-58-1	Fenvalerate
50-00-0	Formaldehyde
302-01-2	Hydrazine
123-31-9	Hydroquinone
330-55-2	Linuron
121-75-5	Malathion
108-31-6	Maleic anhydride
12427-38-2	Maneb
126-98-7	Methacrylonitrile
94-74-6	Methoxone
109-86-4	Methoxyethanol, 2-
96-33-3	Methyl acrylate
80-62-6	Methyl methacrylate
2439-01-2	Methyl-1,3-dithiolo[4,5-b]quinoxalin-2-one, 6-
101-14-4	Methylenebis(2-chloroaniline), 4,4'-
101-77-9	Methylenedianiline, 4,4'-
2212-67-1	Molinate
300-76-5	Naled
7440-02-0	Nickel
76578-14-8	Quizalofop-ethyl
122-34-9	Simazine
100-42-5	Styrene
35400-43-2	Sulprofos
127-18-4	Tetrachloroethylene
28249-77-6	Thiobencarb
62-56-6	Thiourea
137-26-8	Thiram
108-88-3	Toluene
26471-62-5	Toluene diisocyanate
95-53-4	Toluidine, o-
52-68-6	Trichlorfon
71-55-6	Trichloroethane, 1,1,1-
79-00-5	Trichloroethane, 1,1,2-
1582-09-8	Trifluralin
108-05-4	Vinyl acetate
75-35-4	Vinylidene chloride
75-35-4	Vinylidene chloride
1330-20-7	Xylene
12122-67-7	Zineb