Hirao School of Management Review (2013), Vol.3, pp.66-91.
原稿種別：論文(Article)



# Empirical Study on the Relationship between Environmental Management, Productivity and Profitability at the Firm Level: The Case of Japan

Kenichi Shimamoto*

【Abstract】

Under the sustainable development trend, the interests of environmental management amongst firms have grown. In order for firms to achieve sustainable development, they will need to not only make considerations for the environment, but also to maintain their business operations through productivity and profitability. This paper has examined the effect of environmental management on both productivity and profitability As a result of focusing on Japanese firms in manufacturing, gas and electricity and construction industry, it was found that strong performance in environmental management lead to higher productivity. However, the relationships between environmental management and profitability did not show significant results although the environmental management had a positive impact on profitability in most of the cases.

【Keywords】

environmental management, productivity, profitability, Japan

* Hirao School of Management, Konan University

## 1. Introduction

At the Rio Earth Summit in 1992, there was a global agreement on the need for 'sustainable development' and it has become a goal for economic and social progress (Kanehara and Kaneko, 2005). Under the influence of such focus on sustainable development, firms have continued to express interest in environmental management. Environmental management refers to the management of a firm's activity so that the negative impact it has on the global environment is kept to a minimum and it aims to increase the firm's value. For example, developing, implementing and maintaining policy for the preservation of the natural resource base with effective measures to prevent environmental degradation. In other words, for firms to conduct its business operations according to sustainability principles. The adoption of such a management by a large number of firms will work towards sustainable development and also to increase their value. This paper will examine the extent in which environmental management has on a firm's profitability. Firms under environmental management would need to reduce its input of natural resources and energy and improve its production process to minimize pollution emissions as well as improve productivity in order to minimize their impact on the environment. This paper will examine evidence of environmental management affecting its productivity and to the extent of the impact. In other words, it will examine the effects mentioned in the Porter Hypothesis which suggests that environmental restrictions will trigger the discovery and introduction of cleaner technologies and environmental improvements, making production processes and products more efficient and improve profitability (Porter and van der Linde, 1995).

There are several studies to theoretically examine the argument made in the Porter Hypothesis by Porter and van der Linder (1995). For example, Mohr (2002) supports the hypothesis by using a general equilibrium framework with a large number of agents, external economies of scale in production, and discrete changes in technology.

Previous empirical studies analyse the relationship between environmental regulations and productivity. For example, Murty and Krumar (2003) examine sugar industry of India during the period between 1996 and 1999. The results found that the technical efficiency of firms increases with the degree of compliance of rims to the environmental regulation and water conservation efforts. Alpay et al. (2002) find that Mexico's rising environmental standards have enhanced food processors' productivity growth. Berman and Bui (2001) analyse the case of oil refineries industry of US, finding the evidence to support positive relationship between environmental regulation and productivity.

Differentiations of this paper from the above empirical studies are as follows. First, instead of examining environmental regulations, it will use detailed and various environmental management indexes. Second, this paper will focus on not only the relationship between firms' environmental management and productivity but also the relationship between firms' environmental management and profitability. Third, previous studies focus on a specific or limited industry. Therefore, this study will examine a wider category of industries, i.e. manufacturing, gas and electricity and construction industries.

This study is organized into four sections. Section 2, explains the data manipulation concerning the productivity index and the environmental management indexes. This section also explains other independent variables which will affect both the productivity and profitability. Section 3 will examine the relationship both between the environmental management and productivity and between environmental management and profitability. Section 4 will give the conclusion and policy implications.

## 2. Model and Data

*2-1 Productivity Index*

The productivity will be measured using data envelopment analysis (DEA).

Let $\boldsymbol{x}$ = { $x_1^t$,........, $x_N^t$ } $\in R_+^N$ , where $\boldsymbol{x}$ is input vector. Capital and labour will be included. $\boldsymbol{y}$ = { $y_1^t$,......., $y_M^t$ } $\in R_+^M$ , where $\boldsymbol{y}$ is output vector. Then production possibilities set are defined as

$$P^t \equiv \{(x^t, y^t) : x^t \text{ can produce } y^t\},\ t = 1,\dots\dots\dots,T \tag{1}$$

The production possibilities set satisfy strong disposability of outputs and are closed, bounded and convex. Then a functional form of the production technology can be defined by Shephard's output distance function (Shephard, 1970).

$$D^t(x^t, y^t) = \inf\{\theta : (y^t/\theta) \in P^t(x^t)\},\ t = 1,\dots\dots.,T$$

$$= (\sup\{\theta : \theta y^t \in P^t(x^t)\})^{-1},\ t = 1,\dots\dots.,T \tag{2}$$

where superscript $t$ on $D^t$ denotes that technology in period $t$ is used as the reference technology. $\theta$ is a scalar, and its value is the efficiency score for each production activity. It satisfies $0 < \theta \leq 1$ for a non-negative output level, with a value of 1 representing a point on the frontier and which makes it a technically efficient production activity. This output distance function is defined as the reciprocal of the maximal proportional expansion of vector $\mathbf{y}^t$ with given input vector $\mathbf{x}^t$ in relation to the technology at $t$.

The non-parametric linear-programming techniques was applied by Färe et al. (1994). To calculate the output oriented efficiency index relative to the various-returns-to-scale (VRS) technology, $D$ for each industry, $j \in k = 1, \ldots, K$, one of the four different linear-programming problems, can be stated as:

$$[D_i^t(x_i^t, y_i^t)]^{-1} = \max_{\theta,\, w} \theta_i \tag{3}$$

$$\text{subject to } \theta_i y_{m,i}^t \leq \sum_{k=1}^{K} w_k^t y_{m,k}^t \quad m = 1, \ldots, M \tag{3-1}$$

$$\sum_{k=1}^{K} w_k^t x_{n,i}^t \leq x_{n,i}^t \quad n = 1, \ldots, N \tag{3-2}$$

$$w_k^t \geq 0 \quad k = 1, \ldots, K \tag{3-3}$$

$$\sum_{k=1}^{K} w_k^t = 1 \tag{3-4}$$

where $n = 1, \ldots, N$ are inputs, $m = 1, \ldots, M$ are outputs, and $w_k^t$ is an intensity variable indicating the production intensity of a particular activity (here, each firm is an activity). These intensity variables are applied as weights to take convex combinations of the observed outputs and inputs in both (3-1) and (3-2). In equation (3), the reciprocal of the output distance function is applied to find the maximum of $\theta$, which provides the maximal proportional expansion of output given constraints (3-1) - (3-4)[1].

*2-2 Data*

*Environmental Management Indexes (EM)*. Next, I will explain about the definition of data concerning environmental performance. The Nihon Keizai Shimbun (2000) dataset was constructed from the survey results of a questionnaire that was sent to all publicly quoted companies and a random selection of major non-public companies in the Japanese manufacturing sector and selected non-manufacturing industries (*construction* and *electricity*

[1] VRS adds (3-4) constraint into constant-return-scale (CRS) technology, which represents the convexity constraint.

*and gas*).[2] The survey was conducted between the beginning of October and the middle of November 1999. The purpose of the questionnaire was to gather detailed information regarding the environmental management practices of Japanese firms.

In total, data were obtained from 875 firms representing a response rate of 44 per cent. Of the 875 responses, it was possible to match other firm level data from Toyo Keizai Shinpo (2000a and 2000b) to approximately half of them. The result is an overall sample of around 460 firms. Each of our environmental performance indexes is derived from the marks attributed to the answers to one of thirteen multi-part questions. To allow comparison across indexes, each measure is standardised around a mean of fifty with a standard deviation of ten.[3]

Thirteen of our fourteen indexes are allocated to one of two distinct groups with the fourteenth being an overall summary statistic. The Model 2-8 of Table 2-6 are concerned with the quality of the general structure and systems that firms employ to handle environmental issues. Examples include the disclosure of environmental information (on products and on the treatment of chemicals) and the acquirement of the ISO 14001 certification. The Model 9-14 of Table 2-6 relate to the management, and control of, specific environmental problems. Examples include the management of total $CO_2$ emissions and the outsourcing of the treatment of industrial waste. The overall environmental management performance measure is constructed from a principal components analysis of the other thirteen indices (Model 1 of Table 2-6). The data definition of these environmental management indicators are described in Appendix B.

To help interpret the basic scores a firm receives for each variable it is useful to briefly clarify how the survey results were constructed. Each index is constructed from the answer to one of thirteen questions each of which contains a number of parts, although our data do not allow us to distinguish between the answers or weightings that are given to the different parts of each question. However, with the exceptions of Total Industrial Waste Management, Total Treated Industrial Waste Management and Management of $CO_2$ emissions, each index is derived purely from questions relating to environmental management rather than actual environmental performance. Even for these exceptions, only one part in six of the question relates to changes in actual emissions or waste.

These environmental managements may encourage technological innovation which will lead to the enhancement of the productivity as the Porter Hypothesis implies. On the other hand, these environmental managements may incur environmental costs which will hinder productivity. Hence

[2] See Appendix A for a list of industries.

[3] The standardisation procedure is $50+10*(X-\overline{X}/s.d)$ where X is the initial value for each environmental management indicator. It should be noted that the standardisation applies to our matched sample of firms and not the 875 replies from the original survey. The result is that the means are generally greater than the standardised level of 50. This reflects the fact that the matching data was biased towards larger firms that, *ceteris paribus*, are more likely to have environmental management systems in place.

the expected sign will be undetermined. The firms which are successful in responding the environmental requirements will take advantage in terms of reputation from society which may include consumers and may have a positive impact on profit. However, the opposite may be true since the environmental responses by firms may incur an extra burden on their business and lead to less profit[4]. For the case of the relation between environmental management and profitability, the expected sign will be undetermined.

Other than environmental management indexes, additional independent variables examined are explained below.

*Foreign Direct Investment (FDI).* Concerning FDI which represents globalization, overseas affiliates are more likely to employ advanced technological and knowledge solutions in order to maintain a competitive edge and to thus compensate for any lack of local knowledge (Kindleberger, 1969; Hymer, 1976). This information, in turn, could then form the foundation for technological and knowledge improvements at home, which will encourage the enhancement of productivity[5] and profitability. Therefore, the expected sign will be positive. FDI is measured as the FDI stock divided by assets in the whole firm.

*Net worth ratio (NW).* The net worth ratio is an indicator for access to finance. That is, it is used to indicate the access to internal capital. In other words, the higher the net worth, the easier it is to have access to internal capital and the more likely it will be a factor which contributes to investment in areas related to productivity. It will also help not to have to loan from external agencies. The expected sign will be positive for both productivity and profitability. Net worth ratio refers to the percentage of the shareholder's equity of the total capital. The data source is from Toyo Keizai Shinpo's (2000b) Kaisha zaimu Carte (Corporate Finance Carte) for 1999.

*Keiretsu.* Firms which belong to *keiretsu* will have some advantage on the improvement of productivity and profitability since the firms may be able to exchange some information, knowledge and skill without paying the cost and manpower within the 'keiretsu' group. On the other hand, *keiretsu* membership may represent a hindrance to perform perhaps by inflexibility or prolonged internal bureaucratic procedures. Therefore, the expected sign will be undetermined. Following Fukao et al. (1994) if the largest percentage of a firm's loan is from the same main bank for over 3 years then it is considered a *keiretsu* of the bank and the firm is given a dummy variable of 1[6].

Our final estimating equation is therefore:

---

[4] According to Xepapadeas and Zeeuw (1999), downsizing and modernization of firms subject to environmental policy will have positive effects on the marginal decrease of profits. For the case of competitiveness which may have a impact on profitability, Cole et al. (2005) find that environmental regulations will cause the decrease of the competitiveness.

[5] Liu and Wang (2003) find the evidence that FDI had a positive impact on productivity in China. Kokko (1994) also finds the same results for the case of the Mexican manufacturing industry.

[6] The six main banks listed in the firms' *keiretsu* list of Toyo Keizai Shinpo (2000c) are, Mitsui group, Mitsubishi group, Sumitomo group, Fuyo group, Sanwa group and Ikkan group.

$$PRT_i = \alpha_{0i} + \alpha_{1i} EM_i + \alpha_{2i} FDI_i + \alpha_{3i} NW_i + \alpha_{4i} Keiretsu_i + \varepsilon_{1i} \quad (4)$$

$$PRF_i = \beta_{0i} + \beta_{1i} EM_i + \beta_{2i} FDI_i + \beta_{3i} NW_i + \beta_{4i} Keiretsu_i + \varepsilon_{2i} \quad (5)$$

## 3. Results

Before conducting econometric analysis by using the above equation, it is necessary to confirm whether the independent variables chosen in the same equation simultaneously can be used. In order to confirm this, an analysis was conducted using the correlation matrix. As a result, a large value of correlation coefficient was not found. A correlation matrix is provided in Appendix C.

Table 1. Breusch-Pagan Test for Independence of Each Equation (Model1-5)

| | Model1 | | Model2 | | Model3 | | Model4 | | Model5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Corr. of red. | 0.32 | | 0.33 | | 0.32 | | 0.33 | | 0.32 | |
| Breusch-Pagan test | 48.71 | *** | 50.73 | *** | 48.47 | *** | 49.46 | *** | 47.86 | *** |

***significant at 1%; ** significant at 5%; * significant at 10%

Table 1. Breusch-Pagan Test for Independence of Each Equation (Model 6-10)

| | Model6 | | Model7 | | Model8 | | Model9 | | Model10 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Corr. of red. | 0.32 | | 0.32 | | 0.33 | | 0.32 | | 0.32 | |
| Breusch-Pagan test | 48.88 | *** | 47.54 | *** | 49.39 | *** | 47.93 | *** | 48.61 | *** |

***significant at 1%; ** significant at 5%; * significant at 10%

Table 1. Breusch-Pagan Test for Independence of Each Equation (Model 11-14)

| | Model11 | | Model12 | | Model13 | | Model14 | |
|---|---|---|---|---|---|---|---|---|
| Corr. of red. | 0.33 | | 0.33 | | 0.33 | | 0.32 | |
| Breusch-Pagan test | 51.50 | *** | 51.31 | *** | 50.26 | *** | 48.68 | *** |

***significant at 1%; ** significant at 5%; * significant at 10%

According to Table 1 which is the result from the Breusch and Pagan test to confirm the null hypothesis, that error term of each equation is independent, the above equations (4) and (5) were found to be correlated to each other. Therefore, I will use seemly unrelated regression (SUR).

Table 2. Regression Analysis on the Relationship between Productivity (VRS) and Environmental Performance (Model 1-5)

| Productivity(VRS) | Model 1 | | Model 2 | | Model 3 | | Model 4 | | Model 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Overall | 0.042 | *** | | | | | | | | |
| | (5.150) | | | | | | | | | |
| ISO | | | 0.315 | *** | | | | | | |
| | | | (3.420) | | | | | | | |
| ORG | | | | | 0.206 | ** | | | | |
| | | | | | (2.180) | | | | | |
| EFP | | | | | | | 0.325 | *** | | |
| | | | | | | | (4.350) | | | |
| EA | | | | | | | | | 0.416 | *** |
| | | | | | | | | | (5.790) | |
| FDI | 5.530 | *** | 5.302 | *** | 5.391 | *** | 5.471 | *** | 5.898 | *** |
| | (-3.580) | | (3.380) | | (3.410) | | (3.510) | | (3.840) | |
| Net worth | 0.139 | *** | 0.131 | *** | 0.138 | *** | 0.126 | *** | 0.134 | *** |
| | (2.970) | | (2.750) | | (2.870) | | (2.670) | | (2.870) | |
| Keiretsu | -0.049 | *** | -0.049 | *** | -0.049 | *** | -0.048 | *** | -0.041 | ** |
| | (-2.750) | | (-2.750) | | (-2.700) | | (-2.720) | | (-2.310) | |
| Constant | 0.182 | *** | 0.227 | *** | 0.273 | *** | 0.231 | *** | 0.183 | *** |
| | (3.640) | | (4.080) | | (4.530) | | (4.880) | | (3.920) | |
| Obs | 466 | | 466 | | 466 | | 466 | | 466 | |
| R-sq | 0.244 | | 0.220 | | 0.209 | | 0.232 | | 0.254 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Table 2. Regression Analysis on the Relationship between Productivity (VRS) and Environmental Performance (Model 6-10)

| Productivity(VRS) | Model 6 | | Model 7 | | Model 8 | | Model 9 | | Model10 | |
|---|---|---|---|---|---|---|---|---|---|---|
| ES | 0.390 | *** | | | | | | | | |
| | (5.430) | | | | | | | | | |
| WO | | | 0.191 | ** | | | | | | |
| | | | (2.470) | | | | | | | |
| Chem info | | | | | 0.214 | ** | | | | |
| | | | | | (2.480) | | | | | |
| COOP | | | | | | | 0.210 | *** | | |
| | | | | | | | (3.070) | | | |
| Waste | | | | | | | | | 0.200 | *** |
| | | | | | | | | | (2.860) | |
| FDI | 5.710 | *** | 5.353 | *** | 5.350 | *** | 5.504 | *** | 5.435 | *** |
| | (3.700) | | (3.390) | | (3.390) | | (3.500) | | (3.450) | |
| Net worth | 0.137 | *** | 0.141 | *** | 0.133 | *** | 0.145 | *** | 0.140 | *** |
| | (2.920) | | (2.940) | | (2.770) | | (3.030) | | (2.940) | |
| Keiretsu | -0.049 | *** | -0.050 | *** | -0.050 | *** | -0.050 | *** | -0.050 | *** |
| | (-2.780) | | (-2.780) | | (-2.770) | | (-2.800) | | (-2.750) | |
| Constant | 0.048 | *** | 0.287 | *** | 0.296 | *** | 0.274 | *** | 0.288 | *** |
| | (4.000) | | (5.670) | | (6.200) | | (5.690) | | (6.200) | |
| Obs | 466 | | 466 | | 466 | | 466 | | 466 | |
| R-sq | 0.248 | | 0.211 | | 0.211 | | 0.216 | | 0.214 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Table 2. Regression Analysis on the Relationship between Productivity (VRS) and Environmental Performance (Model 11-14)

| Productivity(VRS) | Model11 | | Model12 | | Model13 | | Model14 | |
|---|---|---|---|---|---|---|---|---|
| TW | 0.285 | *** | | | | | | |
| | (3.600) | | | | | | | |
| $CO_2$ | | | 0.200 | *** | | | | |
| | | | (2.620) | | | | | |
| LG | | | | | 0.264 | *** | | |
| | | | | | (3.070) | | | |
| GW | | | | | | | 0.380 | *** |
| | | | | | | | (4.730) | |
| FDI | 5.442 | *** | 5.232 | *** | 5.271 | *** | 5.389 | *** |
| | (3.010) | | (3.320) | | (3.350) | | (3.470) | |
| Net worth | 0.143 | *** | 0.145 | *** | 0.131 | *** | 0.143 | *** |
| | (3.010) | | (3.020) | | (2.750) | | (3.030) | |
| Keiretsu | -0.048 | *** | -0.046 | ** | -0.049 | *** | -0.046 | *** |
| | (-2.670) | | (-2.540) | | (-2.700) | | (-2.600) | |
| Constant | 0.249 | *** | 0.291 | *** | 0.263 | *** | 0.203 | *** |
| | (5.070) | | (6.100) | | (5.170) | | (4.100) | |
| Obs | 466 | | 466 | | 466 | | 466 | |
| R-sq | 0.222 | | 0.212 | | 0.216 | | 0.237 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Table 2 shows that overall environmental management index had a positive and significant impact on the productivity measured by DEA. As a whole, through environmental management, firms may encourage products and process innovation which will lead to the improvement of productivity. All environmental management indexes related to system and structure were statistically significant and positive, suggesting that the improvement of system and structure concerning environmental management will enhance productivity activities. The introduction of environmental management in terms of system and structure will encourage the firms to take environmental issues into account as well as ‘business as usual’, which means that the firms will make an attempt to save resources and energy. In order to maximize the profits under the restrictions of usage of energy and resources, the firms will have to make products and process innovations, which will lead to improvement in their productivity. Concerning *ISO*, since ISO 14001 requires the setup of the goal and policy and procedure regarding environmental management, it will help determine the firms' environmental management. Moreover, as ISO 14001 will be a symbol for international or domestic transaction, and will be linked with the corporation image, the firms will be affected by external pressure. Therefore, the firms will be influenced by the pressure of restrains of energy and resources, which will trigger the enhancement of productivity. Concerning *ES* and *Chem info*, disclosure of environmental statement and chemical information will also encourage the firms to take into consideration the usage of energy and resources since the firms will be subject to external monitoring such as investors. With regards to *EA*, environmental accounting will help to identify the efficient way to use the energy and resources through a financial approach. As for *EFP*, the implementation of Life Cycle Assessment will also encourage firms to improve their efficiency to maximise the usage of energy and resources. Purchasing of green products will lead the firms to develop technology which will be suitable to use in green products. Concerning *ORG*, environmental training for workers and setting up of department and staff responsible for the environmental issues will encourage the awareness or skill on the usage of energy and resources. With respect to *WO*, by outsourcing waste to the relevant agent, the firms will manage to exclude the inefficient process concerning waste management. Recycling technology will encourage the firms to use inputs in an efficient manner. As for *COP*, cooperation with the public will increase exchange of information or techniques regarding the efficient usage of environmental resources. The above eight environmental management indexes will lead to the improvement of productivity. For the case of environmental management related to specific pollutants, all indexes i.e. waste management, $CO_2$ emission management, land and groundwater control and global warming management were statistically significant and positive. Through these environmental managements which minimise pollution, the firms will increase the standard of their productivity.

Table 3. Regression Analysis on the Relationship between Profitability and Environmental Performance (Model 1-5)

| Profitability | Model 1 | | Model 2 | | Model 3 | | Model 4 | | Model 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Overall | 0.023 | | | | | | | | | |
| | (1.140) | | | | | | | | | |
| ISO | | | 0.013 | | | | | | | |
| | | | (0.060) | | | | | | | |
| ORG | | | | | 0.296 | | | | | |
| | | | | | (1.290) | | | | | |
| EFP | | | | | | | 0.144 | | | |
| | | | | | | | (0.780) | | | |
| EA | | | | | | | | | 0.262 | |
| | | | | | | | | | (1.460) | |
| FDI | 58.089 | | 56.996 | | 57.812 | | 57.615 | | 60.563 | |
| | (1.510) | | (1.480) | | (1.500) | | (1.500) | | (1.570) | |
| Net worth | 0.136 | *** | 0.136 | *** | 0.136 | *** | 0.135 | *** | 0.135 | *** |
| | (11.640) | | (11.600) | | (11.640) | | (11.560) | | (11.620) | |
| Keiretsu | -0.730 | * | -0.729 | * | -0.737 | * | -0.729 | * | -0.681 | |
| | (-1.660) | | (-1.650) | | (-1.680) | | (-1.660) | | (-1.540) | |
| Constant | -1.812 | | -0.762 | | -2.295 | | -1.377 | | -1.969 | |
| | (-1.450) | | (-0.560) | | (-1.570) | | (-1.180) | | (-1.690) | |
| Obs | 466 | | 466 | | 466 | | 466 | | 466 | |
| R-sq | 0.398 | | 0.397 | | 0.399 | | 0.398 | | 0.400 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Table 3. Regression Analysis on the Relationship between Profitability and Environmental Performance (Model 6-10)

| Profitability | Model 6 | Model 7 | Model 8 | Model 9 | Model10 |
|---|---|---|---|---|---|
| ES | 0.201 | | | | |
| | (1.120) | | | | |
| WO | | 0.366 ** | | | |
| | | (1.950) | | | |
| Chem info | | | 0.118 | | |
| | | | (0.560) | | |
| COOP | | | | 0.245 | |
| | | | | (1.460) | |
| Waste | | | | | 0.183 |
| | | | | | (1.070) |
| FDI | 58.940 | 57.368 | 57.093 | 58.981 | 57.928 |
| | (1.530) | (1.500) | (1.480) | (1.540) | (1.510) |
| Net worth | 0.136 *** | 0.136 *** | 0.135 *** | 0.136 *** | 0.133 *** |
| | (11.620) | (11.720) | (11.590) | (11.700) | (11.650) |
| Keiretsu | -0.733 * | -0.767 * | -0.739 * | -0.754 * | -0.740 * |
| | (-1.660) | (-1.750) | (-1.680) | (-1.710) | (-1.680) |
| Constant | -1.698 | -2.565 ** | -1.183 | -1.987 * | -1.579 |
| | (-1.430) | (-2.090) | (-1.020) | (-1.690) | (-1.390) |
| Obs | 466 | 466 | 466 | 466 | 466 |
| R-sq | 0.398 | 0.402 | 0.397 | 0.400 | 0.398 |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Table 3. Regression Analysis on theRelationship between Profitability and Environmental Performance (Model 11-14)

| Profitability | Model11 | | Model12 | | Model13 | | Model14 | |
|---|---|---|---|---|---|---|---|---|
| TW | -0.041 | | | | | | | |
| | (-0.210) | | | | | | | |
| $CO_2$ | | | -0.101 | | | | | |
| | | | (-0.540) | | | | | |
| LG | | | | | 0.038 | | | |
| | | | | | (0.180) | | | |
| GW | | | | | | | 0.221 | |
| | | | | | | | (1.110) | |
| FDI | 56.856 | | 57.524 | | 56.919 | | 57.324 | |
| | (1.480) | | (1.490) | | (1.480) | | (1.490) | |
| Net worth | 0.135 | *** | 0.135 | *** | 0.135 | *** | 0.136 | *** |
| | (11.590) | | (11.560) | | (11.590) | | (11.650) | |
| Keiretsu | -0.729 | * | -0.740 | * | -0.729 | * | -0.716 | |
| | (-1.650) | | (-1.680) | | (-1.650) | | (-1.630) | |
| Constant | -0.502 | | -0.229 | | -0.870 | | -1.750 | |
| | (-0.420) | | (-0.200) | | (-0.700) | | (-1.430) | |
| Obs | 466 | | 466 | | 466 | | 466 | |
| R-sq | 0.397 | | 0.397 | | 0.397 | | 0.398 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Concerning the relationship between profitability and environmental management, Table 3 shows that *Overall* had positive impact on profitability but the result was not statistically significant. As for the environmental management indexes related to systems and structures, *WO* had a significant and positive impact on productivity. All other indexes related to systems and structures such as *ISO* and *ES* were positive but insignificant. For the case of environmental indexes related to specific pollutants, *Waste*, *LG* and *GW* were positive but insignificant. *TW* and $CO_2$ were negative and insignificant. In general, environmental management had a positive impact on the profitability but the results were insignificant. In sum, environmental management encouraged the improvement of productivity since the environmental management may stimulate technological innovation, but it did not cause the enhancement of profitability.

To make sure of the robustness of results from Table 2, instead of applying the productivity index measured by DEA, this analysis will use the traditional measurement of productivity based on Cobb-Douglas production function, since the above DEA does not define the production function. The measure of TFP stems from a Cobb-Douglas production function specified as follows;

$$Y = A K^{\alpha} L^{\beta} \quad \text{where } 0 < \alpha < 1 \text{ and } 0 < \beta < 1 \tag{6}$$

$Y$ denotes output, $A$ represents an index of total factor productivity, $K$ represents the total physical capital stock, $L$ denotes the industry's labour force. It did not restrict ($\alpha+\beta$) to equal one and hence allow for the possibility of increasing or decreasing returns to scale. To obtain equation (6) in per worker form, it was divided by the labour force, $L$.

$$y = A k^{\alpha} L^{\alpha + \beta - 1} \tag{7}$$

where $y$ represents output per worker and $k$ denotes the physical capital stock per worker. Expressing equation (7) in natural logarithms provides equation (8);

$$\ln y = \ln A + \alpha \ln k + (\alpha + \beta - 1)\ln L \tag{8}$$

Note that the nature of the production function's returns to scale can now be ascertained by the coefficient on ln$L$. Equation (8) leads directly to equation (9), the equation to be estimated;

$$\ln y_i = \phi_i + + \alpha \ln k_i + (\alpha + \beta - 1)\ln L_i + \varepsilon_i \tag{9}$$

Where subscripts $i$ denote firm. The measure of total factor productivity is then ($\phi_i + \varepsilon_i$) which is equivalent to ln $A$ in equation (8). Table 4 shows the results.

Table 4. Results from the Cobb-Douglas Production Function

| *variable* | *Coefficient (t-statistic)* |
|---|---|
| *lnk* | 0.356 (9.3)*** |
| *lnL* | 0.075 (3.1)*** |
| $R^2$ | 0.18 |
| n | 465 |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Both coefficients were statistically significant and therefore it uses the coefficient to calculate productivity for each firm sampled[7].

Table 5. Robustness for Table 2: Model 1-5

| Productivity(CD) | Model1 | | Model2 | | Model3 | | Model4 | | Model5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Overall | 0.069 | ** | | | | | | | | |
| | (2.520) | | | | | | | | | |
| ISO | | | 0.811 | *** | | | | | | |
| | | | (2.660) | | | | | | | |
| ORG | | | | | 0.562 | * | | | | |
| | | | | | (1.790) | | | | | |
| EFP | | | | | | | 0.252 | | | |
| | | | | | | | (1.000) | | | |
| EA | | | | | | | | | 0.690 | *** |
| | | | | | | | | | (2.840) | |
| FDI | 11.770 | ** | 11.366 | ** | 11.602 | ** | 11.551 | ** | 12.380 | ** |
| | (2.270) | | (2.190) | | (2.230) | | (2.210) | | (2.380) | |
| Net worth | 0.537 | *** | 0.518 | *** | 0.536 | *** | 0.525 | *** | 0.527 | *** |
| | (3.410) | | (3.290) | | (3.390) | | (3.310) | | (3.350) | |
| Keiretsu | -0.156 | *** | -0.159 | *** | -0.158 | *** | -0.156 | *** | -0.143 | ** |
| | (-2.630) | | (-2.670) | | (-2.640) | | (-2.610) | | (-2.410) | |
| Constant | 7.274 | *** | 7.202 | *** | 7.303 | *** | 7.489 | *** | 7.273 | *** |
| | (1.500) | | (38.780) | | (36.400) | | (47.020) | | (46.030) | |
| Obs. | 465 | | 465 | | 465 | | 465 | | 465 | |
| R-sq | 0.137 | | 0.138 | | 0.131 | | 0.127 | | 0.140 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

[7] The elasticity of output with respect to the physical capital stock ($\alpha$) is 0.36. Since the coefficient of $\ln L$ represents ($\alpha + \beta - 1$), the implied elasticity of output with respect to the labour force ($\beta$) is 0.715.

Table 5. Robustness for Table 2: Model 6-10

| Productivity(CD) | Model 6 | | Model 7 | | Model 8 | | Model 9 | | Model10 | |
|---|---|---|---|---|---|---|---|---|---|---|
| ES | 0.641 | *** | | | | | | | | |
| | (2.650) | | | | | | | | | |
| WO | | | 0.274 | | | | | | | |
| | | | (1.070) | | | | | | | |
| Chem info | | | | | 0.209 | | | | | |
| | | | | | (0.730) | | | | | |
| COOP | | | | | | | 0.056 | | | |
| | | | | | | | (0.240) | | | |
| Waste | | | | | | | | | 0.428 | * |
| | | | | | | | | | (1.850) | |
| FDI | 12.063 | ** | 11.472 | ** | 11.459 | ** | 11.489 | ** | 11.660 | ** |
| | (2.320) | | (2.200) | | (2.190) | | (2.200) | | (2.240) | |
| Net worth | 0.533 | *** | 0.539 | *** | 0.529 | *** | 0.535 | *** | 0.540 | *** |
| | (3.380) | | (3.400) | | (3.330) | | (3.370) | | (3.420) | |
| Keiretsu | -0.157 | *** | -0.159 | *** | -0.158 | *** | -0.156 | *** | -0.159 | *** |
| | (-2.650) | | (-2.650) | | (-2.630) | | (-2.610) | | (-2.660) | |
| Constant | 7.288 | *** | 7.469 | *** | 7.523 | *** | 7.579 | *** | 7.402 | *** |
| | (45.390) | | (44.350) | | (47.440) | | (47.220) | | (48.080) | |
| Obs. | 465 | | 465 | | 465 | | 465 | | 465 | |
| R-sq | 0.138 | | 0.127 | | 0.126 | | 0.125 | | 0.131 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Table 5. Robustness for Table 2: Model 11-14

| Productivity(CD) | Model11 | | Model12 | | Model13 | | Model14 | |
|---|---|---|---|---|---|---|---|---|
| TW | 0.636 | ** | | | | | | |
| | (2.420) | | | | | | | |
| $CO_2$ | | | 0.176 | | | | | |
| | | | (0.690) | | | | | |
| LG | | | | | 0.688 | ** | | |
| | | | | | (2.420) | | | |
| GW | | | | | | | 0.735 | *** |
| | | | | | | | (2.730) | |
| FDI | 11.684 | ** | 11.358 | ** | 11.279 | ** | 11.551 | ** |
| | (2.250) | | (2.170) | | (2.170) | | (2.230) | |
| Net worth | 0.547 | *** | 0.540 | *** | 0.518 | *** | 0.544 | *** |
| | (3.470) | | (3.400) | | (3.290) | | (3.460) | |
| Keiretsu | -0.155 | *** | -0.154 | ** | -0.157 | *** | -0.152 | ** |
| | (-2.610) | | (-2.570) | | (-2.640) | | (-2.560) | |
| Constant | 7.306 | *** | 7.527 | *** | 7.291 | *** | 7.257 | *** |
| | (44.670) | | (47.470) | | (43.320) | | (43.650) | |
| Obs. | 465 | | 465 | | 465 | | 465 | |
| R-sq | 0.136 | | 0.126 | | 0.136 | | 0.139 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Table 5 refers to the case where the dependent variable is represented by the productivity index measured by Cobb-Douglas production function. Table 5 shows that *Overall* had a positive and statistically significant impact on the productivity. Since *Overall* which represent overall index of the environmental management was the same result as the one from Model 1 of Table 2 which is based on DEA, with environmental management generally having a positive impact on productivity. When observing each environmental management, eight of thirteen indexes showed positive and statistically significant results. All thirteen indexes were also positive signs which were the same as the results based on DEA measured productivity. In sum, concerning the relationship between environmental management and productivity, robustness was found. Other than environmental management indexes, the results of globalization (*FDI*), access to finance (*NW*), and *Keiretsu* in the case of model 2-14 of Table 5 were the same as ones from Model 2-14 of Table 2. That is, globalization and accessibility to capital had a positive and significant impact on productivity while *Keiretsu* had a negative and significant influence on productivity. These results were also proved to be robust.

Table 6. Robustness for Table 3: Model 1-5

| Profitability | Model1 | | Model2 | | Model3 | | Model4 | | Model5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Overall | 0.023 | | | | | | | | | |
| | (1.150) | | | | | | | | | |
| ISO | | | 0.015 | | | | | | | |
| | | | (0.070) | | | | | | | |
| ORG | | | | | 0.302 | | | | | |
| | | | | | (1.310) | | | | | |
| EFP | | | | | | | 0.145 | | | |
| | | | | | | | (0.780) | | | |
| EA | | | | | | | | | 0.263 | |
| | | | | | | | | | (1.460) | |
| FDI | 58.135 | | 57.019 | | 57.887 | | 57.648 | | 60.600 | |
| | (1.510) | | (1.480) | | (1.500) | | (1.500) | | (1.570) | |
| Net worth | 0.136 | *** | 0.136 | *** | 0.136 | *** | 0.135 | *** | 0.135 | *** |
| | (11.630) | | (11.590) | | (11.630) | | (11.550) | | (11.600) | |
| Keiretsu | -0.731 | * | -0.729 | * | -0.739 | * | -0.730 | * | -0.681 | |
| | (-1.660) | | (-1.650) | | (-1.680) | | (-1.660) | | (-1.540) | |
| Constant | -1.834 | | -0.779 | | -2.350 | | -1.391 | | -1.982 | |
| | (-1.460) | | (-0.560) | | (-1.590) | | (-1.180) | | (-1.690) | |
| Obs. | 465 | | 465 | | 465 | | 465 | | 465 | |
| R-sq | 0.398 | | 0.397 | | 0.399 | | 0.397 | | 0.399 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Table 6. Robustness for Table 3: Model 6-10

| Profitability | Model 6 | | Model 7 | | Model 8 | | Model 9 | | Model10 | |
|---|---|---|---|---|---|---|---|---|---|---|
| ES | 0.202 | | | | | | | | | |
| | (1.120) | | | | | | | | | |
| WO | | | 0.368 | ** | | | | | | |
| | | | (1.960) | | | | | | | |
| Chem info | | | | | 0.119 | | | | | |
| | | | | | (0.560) | | | | | |
| COOP | | | | | | | 0.246 | | | |
| | | | | | | | (1.470) | | | |
| Waste | | | | | | | | | 0.183 | |
| | | | | | | | | | (1.070) | |
| FDI | 58.981 | | 57.417 | | 57.118 | | 59.026 | | 57.958 | |
| | (1.530) | | (1.500) | | (1.480) | | (1.530) | | (1.510) | |
| Net worth | 0.136 | *** | 0.136 | *** | 0.135 | *** | 0.136 | *** | 0.136 | *** |
| | (11.610) | | (11.710) | | (11.570) | | (11.690) | | (11.630) | |
| Keiretsu | -0.733 | * | -0.769 | * | -0.739 | * | -0.755 | * | -0.740 | * |
| | (-1.660) | | (-1.750) | | (-1.670) | | (-1.710) | | (-1.680) | |
| Constant | -1.715 | | -2.591 | ** | -1.194 | | 2.006 | * | -1.591 | |
| | (-1.440) | | (-2.090) | | (-1.020) | | (-1.700) | | (-1.400) | |
| Obs. | 465 | | 465 | | 465 | | 465 | | 465 | |
| R-sq | 0.398 | | 0.401 | | 0.397 | | 0.399 | | 0.398 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Table 6. Robustness for Table 3: Model 11-14

| Profitability | Model11 | | Model12 | | Model13 | | Model14 | |
|---|---|---|---|---|---|---|---|---|
| TW | -0.040 | | | | | | | |
| | (-0.210) | | | | | | | |
| $CO_2$ | | | -0.101 | | | | | |
| | | | (-0.540) | | | | | |
| LG | | | | | 0.038 | | | |
| | | | | | (0.180) | | | |
| GW | | | | | | | 0.222 | |
| | | | | | | | (1.110) | |
| FDI | 56.880 | | 57.546 | | 56.942 | | 57.359 | |
| | (1.480) | | (1.490) | | (1.480) | | (1.490) | |
| Net worth | 0.135 | *** | 0.135 | *** | 0.135 | *** | 0.136 | *** |
| | (11.580) | | (11.540) | | (11.580) | | (11.640) | |
| Keiretsu | -0.729 | * | -0.740 | * | -0.729 | * | -0.717 | |
| | (-1.650) | | (-1.680) | | (-1.650) | | (-1.630) | |
| Constant | -0.513 | | -0.237 | | -0.880 | | -1.768 | |
| | (-0.420) | | (-0.200) | | (-0.700) | | (-1.430) | |
| Obs. | 465 | | 465 | | 465 | | 465 | |
| R-sq | 0.397 | | 0.397 | | 0.397 | | 0.398 | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

Table 6 examines the profitability based on the SUR model which applies the productivity measured by Cobb- Douglas Production Function and shows that almost all of the environmental management indexes are statistically insignificant as well as the results from Table 3. Access to finance (*NW*) are positive and significant, suggesting the robustness. In most of the models from Table 6, *Keiretsu are* negative and significant, again showing the robustness.

Next, I will examine the elasticity of each independent variable. Table 7 refers to the comparison of the elasticity for globalization (*FDI*), access to finance (*NW*), and *Keiretsu*, and environmental management, using the results from Model 1 (*Overall*).

Table 7.The Elasticity of Each Independent Variable.

| | Productivity (VRS) | | Profitability | |
|---|---|---|---|---|
| Overall | 0.61 | *** | 0.43 | |
| | (5.13) | | (1.14) | |
| FDI | 0.03 | *** | 0.05 | |
| | (3.57) | | (1.5) | |
| NW | 0.16 | *** | 2.06 | *** |
| | (2.97) | | (9.41) | |
| Keiretsu | -0.08 | *** | -0.15 | *** |
| | (-2.74) | | (-1.65) | |

*** significant at 1%; ** significant at 5%; * significant at 10%

Standard errors in parentheses

The results indicate that environmental management had the largest impact on productivity. This implies that through environmental management, firms may succeed in innovating technologies to save energy and resources without significantly damaging their output. The second was capital safety represented by net worth ratio, suggesting that it may be necessary to have stable capital or financial situations in order to enhance productivity, which will have a high cost. Net worth ratio also had the largest impact on profitability. The second largest impact on profitability was environmental management, but the results were not significant.

## 4. Conclusion

The Porter Hypothesis insists that environmental regulations can trigger technological innovation which will lead to improvement of productivity. Environmental regulations can also encourage the firms' environmental management. Therefore, firms' environmental management may enhance productivity. Moreover, firms which are successful in responding to environmental needs are likely to be able to take advantage in terms of evaluation from society, which may contribute to their profitability. This paper has examined the effect of environmental management on both productivity and profitability using econometric analyses. As a result of focusing on Japanese firms in manufacturing, gas and electricity and construction industry, thorough environmental management lead to higher productivity. It was true for both the environmental managements related to systems and structures and ones related to specific pollutants. Compared to the globalization index, accessibility to finance index and keiretsu index, the environmental management had the larger impact on productivity. This may be due to the increasing pressure of environmental concerns, firms' undertaking environmental management are conducting technological innovation to reduce energy and/or resources. While environmental management such as environmental accounting, disclosure of environmental statements and energy savings were relatively effective for the improvement of productivity, environmental management such as environmental cooperation with the public, recycling and $CO_2$ mission were relatively less effective than other environmental management indexes. Therefore, policy makers will need to establish a system to make these areas more effective. The relationships between environmental management and profitability did not show significant results although the environmental management had a positive impact on profitability for most of the cases. In sum, given that environmental policy enhances environmental management, evidence to support the Porter Hypothesis was found in terms of the relationship between environmental management and productivity but the results were not significant for the correlation between environmental management and profitability. This may be because environmental management will contribute to cost reduction since improvement in productivity means a reduction in cost per output. However, environmental management may not necessarily contribute significantly enough to increase revenue that will increase profit despite the reduction in cost. Therefore, it may be necessary to stimulate the environmental awareness of consumers.

**Appendix A. Data Definitions of Industries examined in the Study**

Each of our firms falls into one of the following industries: Food and Beverages, Textiles, Paper and Pulp, Chemicals and Chemical Products, Refined Petroleum Products, Rubber and Plastics Products, Clay and Glass, Iron and Steel, Non-Ferrous Metals and Metal Products, Machinery, Electrical Machinery, Motor Vehicle, Other Transport Equipment, Precision Instruments, Other Manufacturing, Gas and Electrical and Construction.

**Appendix B: Data Definitions of Independent Variables Concerning Environmental Management**

(Source of each variable: Nihon Keizai Shimbun 2000).

| Variable | Definition |
|---|---|
| ISO 14001 (ISO) | Acquirement of the ISO 14001 certification. The variable measures the progress in the acquisition of ISO 14000 across all operations. |
| Environmental Management Structure (ORG) | Records whether a firm has a department designed to focus on environmental affairs, who is in charge and whether there are methods of imparting environmental information to employees. |
| Environmental Friendly Products (EFP) | The variable measures the progress in the implementation of Life Cycle Assessment (LCA) and the level of parts and materials that are bought from green sources. |
| Environmental Accounting (EA) | Measures the structure of the costs associated with managing environmental programs. The variable uses the amount of effort applied to environmental accounting. |

| | |
|---|---|
| Disclosure of Environmental Statement (ES) | The variable evaluates whether environmental statements are provided to shareholders and the level of content. |
| Industrial Waste Outsourcing and Recycling (WO) | The variable uses the degree of control firms have over the outsourced treatment of industrial waste. |
| Disclosure of Chemical Treatment (Chem Info) | Disclosure of information concerning chemicals and their treatment. The value measures the understanding of the situation concerning the amount of usage and emission of chemicals, and the degree of disclosure of information. |
| Environmental Cooperation (COOP) | Measures how a firm cooperates and partners with external agencies such as other firms or research organisations concerning environmental issues. |
| Total Industrial Waste Management (Waste) | Management to control total industrial waste. The variable uses progress in setting targets for managing total industrial waste, the value of the targets and actual reduction of total industrial waste in percentage terms. The results for each part of the question are then summed. |
| Total Treated Industrial Waste Management (TW) | Management of total amount of industrial waste. |
| $CO_2$ Emission Management ($CO_2$) | Management of $CO_2$ emissions. |
| Land and Ground Water Pollution Control (LG) | Management of land and ground water pollution and the activities concerning environmental pollution prevention. The value evaluated a firms understanding of their land and ground water pollution and the implications of dioxin reducing practices. |
| Management of global warming and Energy Saving (GW) | The variable uses the amount of effort put into, for example, for tree planting and energy saving. |
| Overall Environmental Management Performance (Overall) | The overall environmental management performance is calculated by using principle component analysis on the 13 indices listed above. |

**Appendix C. Correlation Matrix on Independent Variables** (no. of obs. 465)

| | Overall | ISO | ORG | EFP | EA | ES | WO | Chem info | COOP | Waste | TW | CO2 | LG | GW | FDI | NW | Keiretsu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Overall | 1.00 | | | | | | | | | | | | | | | | |
| ISO | 0.70 | 1.00 | | | | | | | | | | | | | | | |
| ORG | 0.76 | 0.61 | 1.00 | | | | | | | | | | | | | | |
| EFP | 0.78 | 0.49 | 0.56 | 1.00 | | | | | | | | | | | | | |
| EA | 0.78 | 0.48 | 0.55 | 0.59 | 1.00 | | | | | | | | | | | | |
| ES | 0.80 | 0.52 | 0.59 | 0.60 | 0.71 | 1.00 | | | | | | | | | | | |
| WO | 0.70 | 0.42 | 0.52 | 0.53 | 0.45 | 0.48 | 1.00 | | | | | | | | | | |
| Chem info | 0.77 | 0.52 | 0.50 | 0.55 | 0.56 | 0.61 | 0.46 | 1.00 | | | | | | | | | |
| COOP | 0.64 | 0.30 | 0.48 | 0.50 | 0.46 | 0.54 | 0.44 | 0.44 | 1.00 | | | | | | | | |
| Waste | 0.48 | 0.27 | 0.32 | 0.38 | 0.27 | 0.29 | 0.38 | 0.29 | 0.28 | 1.00 | | | | | | | |
| TW | 0.75 | 0.58 | 0.52 | 0.46 | 0.51 | 0.55 | 0.49 | 0.60 | 0.38 | 0.34 | 1.00 | | | | | | |
| CO2 | 0.68 | 0.40 | 0.42 | 0.45 | 0.49 | 0.48 | 0.47 | 0.52 | 0.34 | 0.27 | 0.59 | 1.00 | | | | | |
| LG | 0.63 | 0.48 | 0.43 | 0.51 | 0.44 | 0.38 | 0.39 | 0.49 | 0.23 | 0.25 | 0.44 | 0.39 | 1.00 | | | | |
| GW | 0.76 | 0.48 | 0.56 | 0.60 | 0.57 | 0.57 | 0.45 | 0.55 | 0.49 | 0.30 | 0.50 | 0.48 | 0.43 | 1.00 | | | |
| FDI | -0.19 | -0.14 | -0.21 | -0.10 | -0.09 | -0.19 | -0.20 | -0.13 | -0.13 | -0.07 | -0.16 | -0.16 | -0.04 | -0.15 | 1.00 | | |
| NW | 0.08 | 0.09 | -0.01 | 0.13 | 0.13 | 0.04 | -0.03 | 0.15 | -0.09 | 0.01 | 0.04 | 0.04 | 0.15 | 0.06 | 0.07 | 1.00 | |
| Keiretsu | -0.01 | -0.02 | 0.02 | -0.04 | -0.12 | -0.01 | 0.07 | -0.02 | 0.09 | 0.04 | -0.01 | -0.04 | -0.06 | -0.02 | -0.06 | -0.46 | 1.00 |

## References


Alpay, E., Buccola S., Kerkvliet , J. (2002), Productivity growth and environmental regulation in Mexican and U.S. food manufacturing, *American Journal of Agricultural Economics* 84(4), 887-901.

Berman, E., Bui L. T. M. (2001), Environmental regulation and productivity: evidence from oil refineries, *Review of Economics and Statistics*, 83, 498-510.

Cole, M.A., Elliott, R.J.R., Shimamoto, K. (2005), Why the grass is not always greener: the competing effects of environmental regulations and factor intensities on US specialization, *Ecological Economics*, 54(1), 95-109.

Färe, R., Grosskopf. S., Norris M., Zhang, Z. (1994), Productivity growth, technical progress and efficiency change in industrial countries, *American Economic Review*, 84, 66-83.

Fukao, K., Izawa, T., Kuninori, M., Nakakita, T. (1994), Taigai chokusetsu toshi no kettei yoin- wagakuni denki sangyo kigyo no panel data niyoru jissho kenkyu, [Determinants of Japanese Foreign Direct Investment- the Empirical Study on the Electronics Industry Firms Using Panel Data], (in Japanese), *Keizai Kenkyu*, 45 (3), 261-278.

Hymer, S. (1976*), The Location of industry and international competitiveness*, Oxford, Oxford University Press.

Kanehara, T., Kaneko, S. (2005), *Analysis of environmental management*, Tokyo, Hakuto shobo.

Kindleberger, C. P. (1969), *American Business Abroad: Six Lectures on Direct Investment*, New Haven: London, Yale University Press.

Kokko, A. (1994), Technology market characteristics and spillovers, *Journal of Development Economics*, 43, 279-293.

Liu, X., C. Wang (2003), Does foreign direct investment facilitate technological progress? evidence from Chinese industries, *Research Policy*, 32, 945-953.

Mohr, R. D. (2002), Technical Change, External Economies, and the Porter Hypothesis, *Journal of Environmental Economics and Management*, 43, 158-168.

Nihon Keizai Shimbun (2000), *Dai 3 kai Kankyo keieido chosa chosa hokokusho*, [Report on 3rd Study of Environmental Management], (in Japanese), Tokyo, Nihon Keizai Shimbun, Inc./ Nikkei Research, Inc..

Murty, M. N., Kumar, S. (2003), Win-win opportunities and environmental regulation: Testing of Porter Hypothesis for Indian manufacturing industries, *Journal of Environmental Management*, 67, 139-144.

Porter, M. E., van der Linde, C. (1995), Towards a new conception of the environment - Competitiveness Relationship, *Journal of Economic Perspective*, 9(4), 97-118.

Shephard, R. (1970), Theory *of Cost and Production Functions*, Princeton, Princeton University Press.

Toyo Keizai Shinpo (2000a*), Kaigai shinshutsu kigyo soran:kaisyabetsuhen*, [Foreign Investing Companies Profiles], (in Japanese), Tokyo, Toyo Keizai Shinpo.

Toyo Keizai Shinpo (2000b), *Kaisya zaimu Carte*, [Corporate Finance Carte], (in Japanese), Tokyo, Toyo Keizai Shinpo.

Toyo Keizai Shinpo (2000c), *'Keiretsu' soran*, ['Keiretsu' Profile], (in Japanese), Tokyo, Toyo Keizai Shinpo.

Xepapadeas, A., de Zeeuw, A. (1999), Environmental policy and competitiveness: The Porter hypothesis and the Composition of Capital, *Journal of Environmental Economics and Management*, 37, 165-182.