ENVIRONMENTAL REGULATION AND PRODUCTIVITY: THE EFFECT OF ENVIRONMENTAL POLICIES ON JAPANESE MANUFACTURING INDUSTRIES

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This paper describes the authors’ attempt to measure effects of environmental regulations imposed on industrial solid waste generation. Productivity was measured using the Luenberger Productivity Index based on Data Envelopment Analysis. The sources of productivity change were examined by decomposing the observed index into efficiency change and technical change components. Results show that Japanese manufacturing industries have entered a stagnant phase and actually showed no high productivity growth during 1990-2006. Furthermore, positive changes in surviving industries mainly result from technological innovation, not from improved efficiency.

Key Words: data envelopment analysis, environmental regulation, industrial waste, Luenberger productivity index

1. INTRODUCTION

Waste generation is closely linked to economic activity. Our economy uses materials taken directly or indirectly from the environment for production processes and returns the resultant waste to the environment. The Brundtland Report (World Commission of Environment and Development, 1987) describes the recent heightened awareness of the potential risks of waste to human health and the environment. The concern also exists that the growth rate of waste generation in developed countries is coupled with economic growth which is particularly important in Japan, where the waste generation problem is coupled with dwindling landfill space. Japanese national and local governments established several environmental policies to prevent pollution from industrial waste emission in the 1990s and 2000s.

However, the implementation of environmental regulations has raised concerns about the impact of pollution abatement on the competitiveness of firms and industries. Robinson (1995) in his paper about the impact of environmental regulations on the productivity of the U.S. manufacturing sector, reports that environmental regulation “diverts economic resources and managerial attention away from productivity-enhancing innovation”. However, Porter (1995) concluded that environmental regulations can often stimulate firms to introduce more innovations that improve their environmental performances and economic growth. Similarly, by investigating the relation between productivity and environmental regulations Jaffe et al. (1995) found benefits of increased innovation that engender a cleaner environment. In more recent study, Domalisky and Weber (2004) found no evidence that environmental regulation caused the decline of the efficiency of U.S. chemical industries during 1988–1993.

Recent papers report analyses of environmental performance using Data Enveloping Analysis (DEA). However, the application area is not the same as that in this study. Managi and Jena (2007) analysed environmental productivity and changes in of SO2, NO2, and SPM emissions in 16 states in India during 1991–2003 using Luenberger Productivity Indices.
The result shows that “the existing environmental management is insufficient to bring about sustainable development in India.” Camarero et al. (2008) examined the environmental performance of OECD countries using Data Envelopment Analysis (DEA) obtained during 1971–2002 and concluded that Switzerland shows “the best environmental performance.” Several studies have analysed productivity performance and waste emissions in a Japanese context, but studies generally assess the interdependence of economy and waste emissions using the Waste Input-Output approach (e.g., Nakamura and Kondo, 2002; Nakamura and Kondo, 2004).

This article first presents national and industry-level data for Industrial Solid Waste (ISW) emissions in Japan and explains the link between pollution abatement and productivity. This study is intended to assess the impact of environmental regulation on the productivity growth of 21 Japanese manufacturing industries between 1990 and 2006 using a relatively new method: the Luenberger Total Factor Productivity Index. More specifically, this paper is intended to elucidate the causes of productivity changes while accounting for ISW emissions. To overcome such objectives, this study applies non-parametric DEA to estimate the directional distance function for measurement of the Luenberger Productivity Index (LPI) of Total Factor Productivity (TFP), which has recently been used in several studies as a tool for empirical analysis (Boussemart et al., 2003, Färe and Grosskopf, 2005; Barross and Peypoch, 2007). The LPI credits producers for simultaneously increasing good outputs and reducing bad outputs such as industrial solid waste. Then LPI is broken down into the technical change index (LTECHCH) and the efficiency change index (LEFFCH). These are similar to the general Malmquist Productivity Index (MPI). The MPI credits the increases in good output but doesn’t credit undesirable output. Then, by comparison of the LPI with undesirable output, LPI without undesirable output and the general MPI, environmental and market efficiency, the impact of environmental regulation on TFP growth in the Japanese manufacturing sector has been analysed.

| Designated resource-saving industries |
|---------------------------------------|
| – Industries required to reduce generation of by-products by ensuring rational use of raw materials and promoting use of by-products as recyclable resources |
| - Pulp and paper |
| - Inorganic chemical manufacturing (excluding salt manufacturing) and organic chemical manufacturing |
| - Iron-making and steel-making/rolling |
| - Primary copper smelting and refining |
| - Automobile manufacturing (including motorised bicycle manufacturing) |

| Designated resource-reutilising industries |
|-------------------------------------------|
| – Industries required to use recyclable resources and reusable parts |
| - Paper manufacturing |
| - Glass container manufacturing |
| - Construction |
| - Rigid PVC pipes and pipe fitting manufacturing |
| - Copier manufacturing |

| Specified resource-saving products |
|-----------------------------------|
| – Products required to ensure rational use of raw materials, prolong product life and reduce generation of used products |
| - Automobiles |
| - Home appliances (television sets, air conditioners, refrigerators, washing machines, microwave ovens, clothes dryers) |
| - Personal computers (including CRTs and liquid crystal displays) |
| - Pinball machines (including rotary types) |
| - Metal furniture (metal storage furniture, shelves, office desks and swivel chairs) |
| - Gas and oil appliances (oil heaters, gas cookers with grills, switch-on gas water heaters, bath heaters with gas burners, oil-fired water heaters) |
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2. INDUSTRIAL WASTE REGULATION IN JAPAN

To reduce environmental burden, it is necessary to promote proper waste disposal, re-use and recycling of materials. However, according to the concepts of the Sound Material-cycle Society (SMS), it is more important first to reduce wastes that are generated by industrial processes. To control waste generation, businesses have been encouraged to incorporate environmental considerations into the development, manufacturing, and distribution stages of products.

The Waste Disposal and Public Cleansing Law, which is Japan's general law for the management of waste, was broadly amended in October 1991, to provide a basis for assurance of proper disposal, the promotion of a reduction in waste generation, and the construction of disposal facilities. These amendments came into effect in July 1992.

To promote waste reduction, Japan established environmental regulations and guidelines. Table 2 summarizes government guidelines for waste treatment and recycling.

### Table 2 Government guidelines for waste treatment and recycling

| By Industry | By Product Category |
|-------------|---------------------|
| 1) Iron and steel | 14) Cassette gas cylinders |
| 2) Textiles | 15) Pinball game machines, etc. |
| 3) Car part manufacturing | 16) Textile products |
| 4) Leasing | 17) Bath tubs and bathroom units |
| 5) Gas | 18) Vending machines |
| 6) Paper/pulp manufacturing | 19) Steel cans |
| 7) Nonferrous metal manufacturing | 20) Motorbikes |
| 8) Electronic/electric device manufacturing | 21) Spring mattresses |
| 9) Cement manufacturing | 22) Dry cell batteries, button batteries |
| 10) Factory-produced housing manufacturing | 23) Aerosol cans |
| 11) Chemicals | 24) Personal computers and peripheral |
| 12) Electricity | 25) Lubrication oil |
| 13) Oil refineries | 26) Kitchen components, devices |
| 14) Rubber product manufacturing | 27) Single-use cameras |
| 15) Glass sheet manufacturing | |
| 16) Automobile manufacturing | |
| 17) Distribution | |
| 18) Coal mining | |

(Source: Ministry of Economy, Trade and Industry).
a National Conference for the Promotion of the Reduction in the Amount of Garbage in September 1992.

It conducts activities through the cooperation of private individuals, businesses and governments. In 1994 the Ministry of Economy, Trade and Industry (METI) introduced the “Guideline for Preparing Pre-Evaluation Manuals in Product Designing to Contribute to the Promotion of the Use of Recycled Resources” to help manufacturers to employ the 3R policy. Subsequently, guidelines 17 industrial associations were compiled for application to their products. A council under METI also prepared and introduced numerous other guidelines related to waste reduction and treatment for 18 industries and 35 products (Table 1). To promote waste reduction, reusing and recycling initiatives in the production phase, the Law for Promotion of Effective Utilisation of Resources was put into force in April 2001 as an amendment to the Resource Recycling Promotion Law, enacted in 1991. It specifies measures for the implementation of the 3R in business, including 3R measures related to the production. In all, 69 products and 10 industries have been designated (Table 2).

3. METHODS

Traditional measures of TFP usually ignore the undesirable outputs. However, Färe et al. (2001) argue “productivity indices that ignore reductions in bad outputs provide an incomplete picture of productivity growth.” Introduced by Caves et al. (1982) the MPI was developed by Färe and Grosskopf (2001); furthering their research, they employed Shepherd’s distance function and a non-parametric linear programming approach to measure productivity changes for OECD countries. The MPI has several benefits that make it an attractive approach for use in this study. It is the Total Factor Productivity index that, following Chambers et al. (1996), can be broken down into efficiency change and technical change indexes. The production of good outputs also engenders to the production of bad outputs. The incorporation of undesirables into a traditional MPI can be problematic for following reason. The MPI computed with bad outputs supposes if good outputs are increased, bad outputs will also be increased (Färe and Grosskopf, 2000). For that reason, another method that can de-couple the production of good and bad outputs should be used. For this study, we follow Färe and Grosskopf (2004), adopting the Luenberger Productivity Index (LPI), which credits producers for decreasing bad outputs without damaging other good outputs. The joint production of good and bad outputs is assumed. This study uses the dataset including inputs and both environmental and market outputs.

(1) Production set Respectively designating $X \in R^M_+$, $Y \in R^N_+$ and $b \in R^l_+$ as vectors of inputs, good outputs, and bad outputs, then the production technology is definable as shown below:

$$P(x) = \{(y, b) : x \text{ can produce } (y, b)\}, x \in R^N_+ (1a)$$

In this study we have three inputs: the number of establishments, the number of employees and raw materials, fuels and electricity. Furthermore, production is a desirable output and ISW emissions as a bad output.

Fig.1 portrays graphical explanation of the production set. Industry A produces $b = 1$ and $y = 3$. Industry B produces $b = 3$ and $y = 5$. Industry C produces $b = 3$ and $y = 3$ and Industry D produces $b = 5$ and $y = 4$.

Assuming a piecewise linear technology, the set $P(x)$ is bounded by 0ABDF0 under weak disposability of the polluting output. The DF is attributable to

![Fig.1 Production set](image1)

![Fig.2 Directional Distance Function](image2)
strong disposability of the desirable output, \( y \). The
good output, \( y \), is null-joint with \( b \), because if \( b = 0 \),
then the only \( y \) with \((y, b) \in P(x) \) is \( y = 0 \).

Industries \( A \), \( B \), and \( D \) are all on the boundary of
\( P(x) \). Industry \( C \) is inside the set \( P(x) \) and is inefficient.
As presented in Fig. 1 we have three assumptions:

Weak disposability of good and bad outputs:

\[(y, b) \in P(x) \text{and } 0 \leq \theta \leq 1 \text{ imply } (\theta y, \theta b) \in P(x) \tag{1b}\]

Strong disposability of good output:

\[(y, b) \in P(x) \text{ and } y \leq y \text{ imply } (\hat{y}, b) \in P(x) \tag{1c}\]

Null jointness of the good and bad outputs means
that good outputs cannot be produced without bad
outputs.

\[if \ (y, b) \in P(x) \text{ and } b = 0 \text{ then } y = 0 \tag{1d}\]

For each period of time \( t=1,...,T \), \( k=1,...,K \)
observations of inputs and outputs are assumed.
Consequently, to satisfy all assumptions described
above, the DEA model is as presented below:

\[p^t(x^t) = \begin{cases} (y^t, b^t): \sum_{k=1}^{K} x^t_k y^t_k + \gamma^t m \geq y^t_m & m = 1, ... M \\ \sum_{k=1}^{K} x^t_k b^t_k = b^t_l \text{ } & l = 1, ... L \\ \sum_{k=1}^{K} x^t_k x^t_k \leq x^t_n \text{ } & n = 1, ... N \\ x^t_k \leq 0 \text{ } & k = 1, ... K \end{cases} \tag{1e}\]

\[\sum_{k=1}^{K} b^t_k > 0 \text{ } k = 1, ... K \tag{1f}\]

Therein \( z^t_k \) are weights.

(2) Directional Distance Function (DDF)

A graphical explanation of DDF is presented
in Fig.2 where \( g=(y,-b) \) is the directional output
distance function vector. For industry \( C \), \( g = (y,-b) = (3, -3) \)
and \( = CE/0g = 0.33 \), a value
which implies that if industry \( C \) adopted
the best-practice methods of production (in this
case a linear combination of industries \( A \) and
\( B \) production methods) it could produce one-
third less pollution and simultaneously increase
the desirable output by one-third. The DDF is
defined as shown below:

\[\delta_0(x, y, b : g_y, -g_b) = \sup \beta : (y + \beta g_y, b - \beta g_b) \in P(x) \tag{2a}\]

To compile LPI, we must to calculate four DDF for
industry \( k \).

The first two are for technology and
observations for time period \( t \) and \( t+1 \). The other
two are mixed periods and observations.

\[D_0^t(x^t, y^t, b^t; y^t, -b^t) \]

\[D_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}) \]

\[D_0^t(x^t, y^t, b^t; y^t, -b^t) \]

\[D_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}) \tag{2b}\]

1) To estimate \( D_0^t(x^t, y^t, b^t; y^t, -b^t) \) at time \( t \)
solve the LP:

\[\text{s.t.} \]

\[\sum_{k=1}^{K} x^t_k y^t_k \geq (1 + \theta) y^t_m \text{ } m = 1, ... M \]

\[\sum_{k=1}^{K} x^t_k b^t_k = (1 - \theta) b^t_l \text{ } j = 1, ... J \]

\[\sum_{k=1}^{K} x^t_k x^t_k \leq x^t_n \text{ } n = 1, ... N \]

\[x^t_k \geq 0 \text{ } k = 1, ... K \tag{2c}\]

2) To estimate \( D_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}) \) at time \( t+1 \)
solve the LP:

\[\text{s.t.} \]

\[\sum_{k=1}^{K} x^{t+1}_k y^{t+1}_k \geq (1 + \theta) y^{t+1}_m \text{ } m = 1, ... M \]

\[\sum_{k=1}^{K} x^{t+1}_k b^{t+1}_k = (1 - \theta) b^{t+1}_l \text{ } j = 1, ... J \]

\[\sum_{k=1}^{K} x^{t+1}_k x^{t+1}_k \leq x^{t+1}_n \text{ } n = 1, ... N \]

\[x^{t+1}_k \geq 0 \text{ } k = 1, ... K \tag{2d}\]

3) To estimate \( D_0(x^t, y^{t+1}, b^{t+1}; y^{t+1} - b^{t+1}) \) at time \( t+1 \)
solve the LP:

\[\text{s.t.} \]

\[\sum_{k=1}^{K} x^{t+1}_k y^{t+1}_k \geq (1 + \theta) y^{t+1}_m \text{ } m = 1, ... M \]

\[\sum_{k=1}^{K} x^{t+1}_k b^{t+1}_k = (1 - \theta) b^{t+1}_l \text{ } j = 1, ... J \]

\[\sum_{k=1}^{K} x^{t+1}_k x^{t+1}_k \leq x^{t+1}_n \text{ } n = 1, ... N \]

\[x^{t+1}_k \geq 0 \text{ } k = 1, ... K \tag{2e}\]

4) To estimate

\[D_0^{t+1}(x^t, y^t, b^t; y^t, -b^t) = \max \beta \] at time \( t+1 \) solve the LP:
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Fig. 3

Luenberger Productivity Index

(3) Luenberger Productivity Index

\[ \text{LPI}_{k}^{t+1} = \frac{1}{2} \left[ \sum_{i} \text{LEVCH}_{i}^{t+1} \right] - \frac{1}{2} \left[ \sum_{i} \text{LTECH}^{t+1} \right] \]

(3a)

Now we break down the LPI into an efficiency change LEFFCH and technical change LTECHCH components:

\[ \text{LEFFCH}_{k}^{t+1} = \text{LEVCH}_{k}^{t+1} \]

(3b)

\[ \text{LTECHCH}_{k}^{t+1} = \frac{1}{2} \left[ \sum_{i} \text{LTECH}^{t+1} \right] \]

(3c)

A graphical explanation of LEFFCH and LTECH are presented in Fig. 3.

The Luenberger efficiency change indicator:

\[ \text{LEFFCH}_{t}^{t+1} = D^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}) - D^{t}(x^{t}, y^{t}, b^{t}) \]

The Luenberger technical change indicator:

\[ \text{LTECHCH}_{t}^{t+1} = \sum_{k} \text{LTECH}_{k}^{t+1} \]

The \( \text{LEFFCH}_{t}^{t+1} \) measures the efficiency changes between period \( t \) and \( t+1 \). It reflects the level of “catching up” to the best-practice frontier.

If \( \text{LEFFCH}_{t}^{t+1} = 0 \), then an observation is made at same distance from the frontier at two time periods, thereby no catching-up to the best-practice frontier occurs between two time periods.

If \( \text{LEFFCH}_{t}^{t+1} > 0 \), then an observation is closer to the frontier at time period \( t+1 \) than that at period \( t \), showing that there is no catching up to the frontier between two periods.

Then, if \( \text{LEFFCH}_{t}^{t+1} < 0 \), meaning that an observation is further from the frontier at time period \( t+1 \) than that at the time period \( t \), then the observation is moving toward the opposite direction of frontier from the time period \( t+1 \) to the time period \( t \).

The \( \text{LTECHCH}_{t}^{t+1} \) measures the shift in the best-practice frontier. If \( \text{LTECHCH}_{t}^{t+1} = 0 \), then no shift exists in the best-practice frontier. If \( \text{LTECHCH}_{t}^{t+1} > 0 \), then the shift of the frontier is in the direction of “more desirable outputs and less undesirable outputs”.

Conversely \( \text{LTECHCH}_{t}^{t+1} < 0 \) shows that the shift of the frontier moved towards “less desirable outputs and more undesirable ones”.

4. DATA

The data examined in this study are national level data that include the annual data for 21 manufacturing industries for 1990-2006. The manufacturing industry is a key industry supporting the Japanese economy. It is the main discharger of industrial waste.

Fig. 4 portrays a graphical explanation of annual ISW emissions by the Japanese industries for the period 1990-2006.

The data for conventional market inputs and outputs for 1990-2006 were taken from the Census of Manufacturers of the Ministry of Economy, Trade and Industry. Data for undesirable output for 1990-2006 were collected from the environmental statistic internet resource of the Ministry of the Environment of Japan. Inputs include numbers of establishments, numbers of employees, and values of raw materials and fuels and electricity consumed.

Desirable output is production and undesirable output is the amount of ISW discharged. This study does not consider any recycled or reused waste, but the amount of waste discharged during the production process of goods production. According to the waste
hierarchy, which has taken many forms over the past decade, reducing the amount of waste discharged through production processes has remained the cornerstone of most waste minimisation strategies. In other words, the aim of the waste hierarchy is to extract the maximum practical benefits from products while generating the minimum amount of waste. Waste reduction is attainable through implementation of new technological processes, substitution of raw materials, and minimisation of resource and energy use.

The “Cplex” and “Gams” software were used to estimate Shepherd’s distance function, directional distance function, the MPI and the LPI for each manufacturing industry for 1990-2006. The 21 Japanese manufacturing industries described above were examined. Columns 3, 5, 7, 9, 11 of Table 3 present the average annual growth rate in number of establishments; number of employees; raw materials, fuel and electricity consumed; production for each manufacturing industry based on Japan Standard Industrial Classification (SIC); and ISW discharged through production process during 1990 to 2006.

Table 3 shows that SIC17, SIC18, SIC19, SIC23 SIC24, SIC26 and SIC30 show negative average growth rates of production. Moreover, the decrease in production of SIC23 and SIC30 is coupled with increased average growth rates of waste emissions. However SIC15, SIC16, SIC20, SIC27, SIC31 and SIC32 increased their average growth rates in production while simultaneously decreasing waste emissions. Table 4 provides summary statistic on the manufacturing industries. It is shown that SIC09, SIC26, SIC27 and SIC30 are relatively labour and material, fuel and electricity intensive industries.

5. RESULTS

The general MPI and two LP indexes - one including undesirable outputs and one excluding bad emissions - were estimated for each industry in each year. The efficiencies for 21 industries are reported in columns 18 and 21 of Table 3 which show that, on average, the productivity change score of Japanese manufacturing industries for 1990-2006 when including undesirable outputs is higher than when undesirable outputs are ignored. However, when compared to the technical change, the latter is greater when waste is not considered. The estimation of average technical efficiency reveals that both LWEFFCH and LEFFCH show a decline, but the technical efficiency is –0.0015 when waste is included, as opposed -0.0213 without waste.

A Wilcoxon matched-pairs signed-rank test was performed for each industry during 1990-2006 to test the null hypothesis that two Luenberger Productivity Indexes - one including and another excluding undesirable outputs - and their components are not different. The test results are shown in Table 3. The TFP indexes were not different in almost all of 21 industries excluding SIC12 and SIC18 and the technical efficiency indexes values of the
two methodologies were not different in following industries: SIC10, SIC11, SIC12, SIC15, SIC17, SIC18, SIC19, SIC22, SIC30 and SIC31. However the technological change indexes differ between LPI and LPIW in fifteen, excluding SIC10, SIC15, SIC17, SIC18, SIC22 and SIC39, of twenty one industries, meaning that the factor of productivity growth is technological change component. From the final column of Table 3 we observe that the average productivity change scores for 1990-2006 when including and excluding undesirable outputs are mixed for Japanese manufacturing industries in the period analysed. For example, nine industries show higher productivity growth when ISW emissions are included: SIC10, SIC15, SIC17, SIC18, SIC20, SIC23, SIC25, SIC26 and SIC32. However SIC09, SIC11, SIC12, SIC13, SIC14, SIC16, SIC19, SIC22, SIC24, SIC27, SIC30 and SIC31 have lower productivity growth when ISW emissions are considered. However the results reflect that all labour and material, fuel and electricity intensive industries, such as SIC09, SIC 26, SIC27 and SIC30, have lower technical change coefficients and higher efficiency change coefficients when ISW emissions are taken in account. In column 22 of Table 3, the MPI is also presented for comparison. The MPI scores display a similar view of productivity changes for Japanese manufacturing industries as the LPI when excluding undesirable outputs. Empirical results confirm the theoretical relation presented by Boussenart et al. (2003) who described that the Malmquist productivity index score overestimates the LPI score. More recently, Balk et al. (2008) introduced an exact relation between Malmquist and LP indexes. Regarding methodology, because the MPI overestimates the efficiency score, the LPI should be chosen when estimating good outputs maximization and when estimating inputs and bad outputs minimization. The differences between the two productivity indexes LPI and LPIW are presented in Fig.5, which shows that the SIC15, SIC17, SIC18 and SIC23 are the industries that experienced the highest average productivity growth values when ISW is included. Their growth far surpasses those of other manufactures. Manufacture of apparel and other (SIC12) and manufacture of electrical machinery, equipment and supplies (SIC27) did not perform well when undesirable outputs were not considered and experienced even greater decline in the LPIW when ISW emissions were taken in account. Fig.6 portrays a graphical explanation of annual productivity changes by industry according to the LPI and LPIW. Fig.6 also shows annual productivity changes by industry for the industries that experienced the highest and the lowest productivity growth according to the LPI and LPIW. From Fig.6 it is apparent that when ISW emissions are not considered, manufacture of pulp, paper and paper products and (SIC15) manufacture of chemical and allied products (SIC17), for both industries the TFP score remain stable during 1990-2006. However when ISW emissions are included the manufacture of pulp, paper and paper products (SIC15) after the stagnation during 1992-1995, the industry starts stable growth in 1995 and achieves the greatest improvement in waste reduction technology in 2004. Manufacture of chemical and allied products (SIC17) also shows TFP growth during 1995-1997 and during 1998-1999 in the presence of undesirable outputsManufacture of petroleum and coal products (SIC18) shows a similar change in TFP when ISW emissions are included and when ignoring pollutants in 1990-1998; during 1998-2006, this industry’s productivity under regulations is higher than when waste is not considered. However manufacture of iron and steel (SIC23) shows higher TFP during 1990-2004 when undesirable outputs are considered, but from 2004, both productivity indexes, LPI and LPIW, are similar. In contrast, the manufacture of apparel and others (SIC12) shows no high productivity growth when ISW emissions are excluded but are more inefficient when undesirable outputs are incorporated. Manufacture of electrical machinery, equipment and supplies (SIC27) shows lower TFP when ISW emissions are included during 2004-2006. We can therefore infer that environmental regulation implementation does not always improve the reduction of waste and raw material and fuel use. Environmental regulatory impact depends on the specialization of production processes, the capability of the manufacturer to minimize resource and energy use and details of the ISW composition. To elucidate the causes of productivity changes while accounting for ISW emissions, we decomposed the LPIW into technical-efficiency change (LWEFFCH), and technological change (LWTECHCH) components, the results are presented in columns 19 and 20 of Table 3. There LWEFFCH represents the diffusion of best-practice technology in the waste minimization of industries; it is attributable to the use of fewer raw materials, lowered fuel and energy use, improvements of technology, and management and organization. In addition, LWTECHCH results from innovations and the adoption of new technologies that allows methods of production to improve and results in the shifting upwards of the production frontier. From Fig.7 it is apparent that here we have six combinations of technical efficiency changes and technological changes, which are as follows: Group 1: Improvements in technological change (LWTECHCH>0) co-exist with improvements in technical efficiency (LWEFFCH>0). Group 2:
Improvement in technological change co-exists with zero technical efficiency. Group 3: Increase in technological change co-exists with deterioration in technical efficiency. Group 4: Decrease in technological change co-exists with improvement in technical efficiency. Group 5: Decrease in technological change co-exists with zero technical efficiency. Group 6: Deterioration in technological change co-exists with deterioration in technical efficiency, the worst combination.

Consequently, based on cross-analysis of data from Table 3 and Fig. 7 we infer that SIC15, SIC17, SIC18 and SIC23 experienced a high productivity growth under environmental regulations because they improved their technological effectiveness.

However, the manufacture of apparel and other (SIC12) and manufacture of printing and allied industries (SIC16) experienced a decline in productivity because of deterioration in technological change. Regarding the manufacture of electrical machinery (SIC27), the industry’s productivity apparently declined because of degraded technical efficiency.
| SC | Industry | Number of establishments | Number of employees | Raw materials, fuels and electricity consumed | Production | Industrial waste | Number of establishments | Number of employees | Raw materials, fuels and electricity consumed | Productivity growth: ignore ISW | Productivity growth: including ISW | Impact of ISW emissions on productivity growth* |
|----|----------|--------------------------|---------------------|----------------------------------------------|------------|----------------|------------------------|---------------------|----------------------------------------------|--------------------------|------------------------------------------|---------------------------------------------|
| 1  |          |                          |                     |                                              |            |                |                        |                     |                                | LEFFCH                  | LTECHIC                  |                                 |
| 2  |          |                          |                     |                                              |            |                |                        |                     |                                | LPI                      | LWEFFCH                  |                                 |
| 3  |          |                          |                     |                                              |            |                |                        |                     |                                | LWTECHIC                | LPIW                      |                                 |
| 4  |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 5  |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 6  |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 7  |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 8  |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 9  |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 10 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 11 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 12 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 13 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 14 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 15 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 16 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 17 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 18 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 19 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 20 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 21 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 22 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |
| 23 |          |                          |                     |                                              |            |                |                        |                     |                                |                          |                          |                                 |

*Change in productivity growth when taking ISW emissions in account (inclusive estimates minus exclusive estimate).

Note: ** statistically significant differences. Wilcoxon matched-pairs signed-ranks test was performed to test the null-hypothesis.
ENVIRONMENTAL REGULATION AND PRODUCTIVITY: THE EFFECT OF ENVIRONMENTAL POLICIES ON JAPANESE MANUFACTURING INDUSTRIES

Fig. 5 Differences between LPI and LPIW for 1990-2006

Fig. 6 Annual productivity changes according to LPIW and LPI
Of 21 Japanese manufacturing industries 12 do not show high productivity growth during 1990-2006 when ISW is considered, as indicated by variations in LP indices. The TFP growth found in several industries under environmental regulations mainly resulted from the innovation of technology rather than efficiency improvement.

However the results also reflect that all labour and material, fuel and electricity intensive industries have lower technical change coefficients and higher efficiency change coefficients when ISW emissions are taken in account.

Therefore, we assumed that environmental regulation implementation does not always help to improve the reduction of waste and raw material and fuel use. The impact of environmental regulations depends on the specialisation of production processes, the ability of a manufacturer to minimize resource and energy use and details of the ISW composition. For comparative purposes, the MPI was used. According to theory, the MPI overestimates the productivity changes. Reasons for these different results are likely due to be attributable to the different forms of the Luenberger and the Malmquist productivity index measures.

6. CONCLUSION

This paper presented analyses of Japanese manufacturing industries efficiencies and productivity growths using the Luenberger Productivity Index. A comparative analysis was conducted between the LPIW in the presence of environmental regulations imposed on ISW generation by 21 manufacturing industries and the LPI which excludes waste. A Wilcoxon matched-pairs signed-rank test was performed for each industry during 1990-2006 to test the null hypothesis that two Luenberger Productivity Indexes - one including and another excluding undesirable outputs - and their components are not different.

The test result shows that we could not reject the null-hypothesis that the two productivity indexes and efficiency change components are same for 19 and 10 industries respectively.

The notional hypothesis that technical change is the same is rejected for 15 of twenty one industries. Both LPI and LPIW values show that the average productivity change scores for 1990-2006 when including undesirable outputs and excluding them are mixed for Japanese manufacturing industries, in the period analysed.
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