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Public Utilities' Corporate Growth and Environmental Conservation: Evidence from Japan

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ABSTRACT

This study explores how public utilities in Japan demonstrate the achievement of both growth and environmental conservation, by using financial performance and environmental impact data from publicly traded companies of power, gas, transport, telecommunication, and postal services before and during the COVID-19 pandemic. First, the regression analyses confirm the Environmental Kuznets Curve (EKC) hypothesis and an inverted N-shaped curve in 2019, 2020, and 2021. Second, the deciding factors are the result of the interaction of the following five points, which have been more encouraged and promoted in Japan in recent years: (1) Regulatory reforms such as energy market opening; (2) investors' emphasis on environment, society, and governance (ESG); (3) guidelines and assessments by economic organizations, rating agencies, and environmental nonprofit groups; (4) citizens' professional ethics and willingness for environmental conservation and social contribution; and (5) endogenous efforts by the public utilities as members of society. Third, an approach that focuses on ESG and total shareholders return (TSR) can contribute not only to the achievement of both growth and environmental conservation but also to the expansion of the academic literature.

Keywords: EKC Hypothesis, Environment, Society and Governance, Total Shareholder Returns
JEL Classifications: L21, Q40, Q56

1. INTRODUCTION

This study explores how public utilities in Japan demonstrate the achievement of both growth and environmental conservation, by using financial performance and environmental impact data from publicly traded companies of power, gas, transport, telecommunication, and postal services before and during the COVID-19 pandemic. Focusing on environment, society, and governance (ESG) activities and total shareholders return (TSR) and based on regression analyses, this study clarifies and discusses the results and presents conclusions and implications for decoupling growth and environmental impact.

The author thinks that this study will provide useful implications to foreign researchers because the challenges facing Japanese public utilities—achieving environmental conservation while growing their financial performance amid increasing competition for customers and investors—are common to all industrialized economies. In particular, the liberalization of the electricity power market in 2016 and the gas market in 2017 has compelled Japanese traditional and regional monopolies to compete with new entrants for customers and investors who value environmental conservation. Some of the new entrants, which are subsidiaries of major telecommunications companies, attract customers by advertising that they primarily generate electricity from renewable energy sources, as seen in Section 3.3.

The author also believes that the two Nobel Prizes in Economics have expanded the frontiers of research, requiring a broader perspective and deeper insight for global researchers. The first is on the analysis of market power and regulation in the field of industrial organization theory, for which Dr. Jean Tirole was awarded in 2014. The latter is on the integration of climate change into long-term macroeconomic analysis in the field of environmental economics, for which Dr. William D. Nordhaus was awarded in 2018.

Therefore, from the perspectives of academic studies, policymaking, and corporate strategy planning, it is important to analyze the growth and environmental conservation commitments of Japanese public utilities. However, the author's thorough review of domestic and international academic journals reveals that almost no prior study has been conducted on Japanese utilities based on the approach adopted in this paper. This paper differs from previous studies in three ways.

First, this paper uses corporates' raw environmental data (e.g., tons, MWh, m^3) rather than rating agencies' scores (e.g., A, AA, 80 points).

The second is that the Environmental Kuznets Curve (EKC) Hypothesis and its advanced theory of an inverted N-shaped curve are applied to the firm analysis through accounting, rather than the conventional and traditional approach applied to countries and regions. In particular, the application of the EKC hypothesis to firms can be considered a novel academic approach.

The third is that the paper employs TSR as one of explanatory variables in the regression analysis. TSR is calculated based on dividends, capital gains, etc. divided by the amount invested. The disclosure of TSR has just begun with the 2019 amendment of the Cabinet Office Order on Disclosure of Corporate Affairs in Japan. Previous studies have never used TSR to analyze environmental data; a TSR analysis can contribute to expanding the research frontier not only in Japan but also in other countries. The author agrees to the recommendation by the Boston Consulting Group (BCG) of Japan. BCG (2021) recommended that TSR should be positioned as medium- and long-term goals to increase corporate value instead of short-term share price appreciation.

Hence, while overcoming the difficulties of raw data collection, this paper endeavors to study the unexplored field of the relationship between public utilities' growth and environmental conservation in Japan.

2. DEFINITIONS, PRIOR STUDIES AND CHALLENGES

2.1. Definitions

This section first defines key terms by introducing the progress of legal amendments in Japan. First, "public utilities" are stipulated by the Article 8 of the Act (No. 25 of 1946) on Labor Relations Adjustment. They are defined as the following businesses that provide services essential to the daily life of the general public: (1) business for supplying water, electricity or gas, (2) transportation businesses, and (3) mail, correspondence delivery or telecommunications. However, there are no examples of public water utility listings; therefore, they are omitted from this paper.

Next, "environmental conservation" is defined by the Article 2 of the Act (No. 91 of 1995) on Basic Environment.

It means preventive measures against global warming, ozone layer depletion, marine pollution, decrease in wildlife species, or situations affecting the whole or part of the world caused by human activities, which contributes to the welfare of humankind as well as to wholesome and cultured living of the people.

The Japanese government declared in 2021 that Japan aims to reduce its greenhouse gas emissions by 46% in 2030 from the 2013 level, setting a target that aligns with the long-term goal of achieving net-zero by 2050, and Japan continues efforts in its challenge to meet the goal of cutting its emission by 50%. In line with the strengthening of the target, the 2021 revised Act (No. 117 of 1998) on Promotion of Global Warming Countermeasures has strengthened its text from "*control*" to "*reduce*" greenhouse gas emissions. For example, Article 5 highlights that "Business entities shall endeavor to take measures to *reduce* greenhouse gas emissions and shall cooperate with measures implemented by the national and local governments to reduce emissions."

Moreover, this paper examines the EKC hypothesis. The EKC hypothesis is an economic theory that illustrates the relation between growth and environmental impacts. This is an application of the theory of economic growth and income inequality postulated by Dr. Simon Kuznets, a Nobel laureate in Economics. The academic discussions on the EKC hypothesis have started in the 1990s by Grossman and Krueger (1991) and World Bank (1992), then, the discussions have extended from air pollutions to water contaminations and deforestation (Benoit et al., 2022; Csereklyei et al., 2017; Galeotti et al., 2009; Gopakumar et al., 2022; Markandya et al., 2006; Panayotou, 1997; Perman and Stern, 1999; Selden et al. 1999; Sorgea and Neumann, 2020; Stern and Common 2001; Tsujimoto 2018 and 2022). Especially, in the hypothesis, environmental impacts increase up to a certain level of economic growth and then start to decrease, showing an inverted U-shaped curve at the turning point. The hypothesis is valid when the linear term (positive: $\beta > 0$) and the squared term (negative: $\beta < 0$) are significant (Figure 1 in Section 3.2).

In addition, the success or failure of a cubic curve is tested, as an applied form of the EKC hypothesis. It is desirable to illustrate an inverted N-shaped curve in investigating the relationship between growth and environmental impact. The inverted N-shape is valid in cases wherein the environmental impact increases (positive: $\beta > 0$) at the first turning point (bottom), it decreases (negative: $\beta < 0$) at the second turning point (top) (Figure 2 in Section 3.2).

2.2. Prior Studies

In the second section, the author discusses prior studies on the relationship between corporate growth and environmental conservation. Prior studies are mostly not based on raw data, such as tons, MWh, and m^3, but secondary ESG scores (e.g., A, AA, and 80 points) issued by rating agencies based on their own criteria.

For example, Kojima (2021) analyzed the relationship between ESG scores and human resources using regression analysis and concluded that ESG initiatives are effective in recruiting human resources in Japan, where lifetime employment has been the norm, and the length of employment period is still important in securing the trust of both individuals and companies. Kojima (2021) illustrated that the retention rate increases by four percentage points and the length of service also expands by 2 years when the ESG score is in the top 25%. The number of Japanese firms surveyed was 488 in the former and 589 in the latter.

However, arbitrariness cannot be eliminated in the scoring when setting the criteria. Yuyama (2019) pointed out that it is difficult to objectively verify whether ESG scores are appropriate or not. Ikuta and Fujii (2020) also pointed out the reliability and comparability of ESG valuation results.

To the best of the author's knowledge, there is no prior research in Japan that has investigated the relationship and combined financial performance and actual environmental impact data, leading to a turning point that achieves both growth and environmental conservation. Therefore, it is appropriate to directly analyze the nonfinancial raw data of CO_2 emissions (tons), electricity consumption (MWh), water consumption (m^3), and industrial waste generation (tons) of public utilities to ensure objectivity.

The primary reason for the absence of prior research that uses raw data is the insufficient disclosure of environment-related information and inconsistent disclosure standards among companies and rating agencies during the transitional period of national and global standard setting. Disclosure requires a certain amount of time and money, including certification by inspection companies, and may involve confidential corporate information.

Moreover, conflicts of opinion among regulatory authorities, industry associations, legal and accounting firms, financial institutions, and media organizations have left the extent of disclosure to the discretion of each company. As a result, listed companies that should have gone public after a series of stringent legal and financial screening processes on the Tokyo Stock Exchange do not always disclose environmental data that can withstand academic verification, compared with the systematic and comprehensive disclosure of financial data.

The second reason for the absence of prior research is that environmental and ESG raw data are disclosed in inconsistent ways and sometimes require time and effort to collect. Unlike financial disclosure, ESG data disclosure by Excel or CSV is not widely used in Japan. Therefore, this study requires careful reading of relevant sections of environmental and/or ESG reports over 100 pages or companies' websites, inputting the data into Excel sheets and reconfirming each figure one by one.

However, despite the time and effort required, the method used in this paper contributes to the exploration of the academic frontier by ensuring the availability of data.

2.3. Impacts and Challenges

Finally, in this section, the author discusses the economic and environmental impacts and challenges of the targeted 43 stock-listed public utilities. Some of them are leaders in their respective industries, which develop and export cutting-edge technologies, in terms of net sales and the number of employees. The other public utilities are facing falling revenues due to a declining population by providing regional transport services for mountainous or island regions. However, all the 43 public utilities targeted provide essential services, despite the differences in size and name recognition (see the complete list of the names of the companies in Table A1).

The following are the economic and environmental impacts of the 43 public utilities. Among the sales of the total 3,830 listed companies on the Tokyo Stock Exchange as at July 2022, the consolidated sales of the public utilities in 2021 accounted for 8.7%; the utilities' sales are JPY 72.38 trillion (USD 538.80 billion), while the total listed sales are JPY 834.84 trillion (approximately USD 6.21 trillion). Although the utilities' sales in 2021 decreased by 7.6% from 2019, Scope 1 CO_2 emissions (definition in 3.1) in 2021 increased by 11.6% from 2019, reaching 203.11 million tons. Moreover, the utilities' sales and Scope 1 CO_2 emissions are comparable to Belgium's GDP of USD 521.26 billion and the UAE's 193.51 million tons of CO_2 emissions in 2021 (International monetary fund (IMF), 2022; European Commission, 2022).

In addition to the spread of IT-based workstyles, the hopeful recovery of daily life and industrial activities during and after the COVID-19 pandemic and the increase in electricity consumption and CO_2 emissions has been forecasted. Japan Science and Technology Agency (JSTA, 2021), in fact, have sounded the alarm regarding the insufficient power supply and network infrastructure and proposes energy conservation at data centers, as domestic power consumption will be 90 TWh in 2030 and 12,000 TWh by 2050, compared to 14 TWh in 2018 with the spread of cloud services, medical image diagnosis, and face recognition. So, power saving and decarbonization of data centers will become even more important.

Hence, achieving both growth and environmental conservation by public utilities is more important, and despite the importance of academic studies, policymaking, and corporate strategy planning, there is an absence of previous research, as above-mentioned. Therefore, this paper will explore that unexplored frontier.

3. VERIFICATION

3.1. Method

This section verifies the relationship between the financial performance and environmental impact data in the listed public utilities in Japan, employing linear, quadratic, and cubic regressions. The method is outlined below.

- Targeted public utilities: of the 3,832 companies listed on the Tokyo Stock Exchange as of June 30, 2022, 43 were chosen from electric power, gas, transportation, telecommunications, and postal services, for which environmental data are available.

- Number of companies by sector: electric power - 11, gas -7, transportation -19, telecommunications -5, postal services -1. See Table A1 at the end of the paper for complete company names.
- The dependent and explanatory variables are as follows (Table 1).
- Dependent variables: 16 = 8 × 2 [both cases are divided and not divided by persons (per staff member)]. There are both patterns in which it is calculated on a per staff member basis and not; 8 patterns for the former and 8 patterns for the latter, for a total of 16 patterns. The reason for dividing by per capita is to analyze more accurately the differences in sales and the number of employees.
- Explanatory variables: 14 = 7 × 2 (both cases are divided and not divided by persons). As in the dependent variables, both cases are a per staff member basis and otherwise; that is, there are 7 patterns for the former and 7 patterns for the latter, for a total of 14.
- The total number of regression formulas is 1,008. The breakdown is as follows;
- The number of formulas is 336 in 2019, 336 in 2020 and 336 in 2021, respectively.
- The 336 equations are broken down as follows: 336 equations = 112 (linear) + 112 (quadratic) +112 (cubic).
- The smallest breakdown of 112 linear equations = 8 (dependent variables) × 7 (explanatory variables) × 2 (both cases divided by persons and not).
- The smallest breakdown of 112 quadratic and 112 cubic equations is the same as that of the linear equation.

The verification of CO_2 employs Scope 1 (direct emissions) and supply chain emissions, which include the sum of the entire flow, from raw material procurement, manufacturing, distribution, and sales to disposal. The overall emissions activities should be captured without being passed on to upstream and downstream firms. Definitions of Scope 1-3 (US Environment Agency, 2021) are as follows.

- Scope 1: direct emissions by the business itself.
- Scope 2: indirect emissions from the use of electricity, heat, and steam supplied by other companies.
- Scope 3: indirect emissions other than Scopes 1 and 2; emissions of other companies related to business activities, consisting of 15 categories, including employees' commuting and business travel.
- Target year of data: Cross-sectional data analysis for 2019, 2020, and 2021. Available environmental impact data before 2018 is insufficient or inconsistent, rendering time series analysis impossible; most Japanese companies did not disclose environmental data prior to 2018. For example, Japan's leading Tokyo Electric Power Company (TEPCO) and Chubu Electric Power Company fully transitioned and integrated their existing thermal power plants into a newly established subsidiary in 2019. As a result, there is a disconnect in environmental impact data. TEPCO's Scope 1 CO_2 emissions (million tons) were 0.2 in 2019, compared with 816 in 2018. Moreover, the regression analysis requires at least 3-4 years of data in the difference equation to prevent spurious regression.

Though the data is limited, it illustrates the circumstances of each public company before and during the COVID-19 pandemic, disclosing certain implications in the relationship between growth and conservation; this paper discusses inductively to find certain criteria and rules from the disclosed information.

- Sources
  - I. Financial data: Japan's annual securities reports (Yuka Shouken Hokokusho, abbreviation: Yuho in Japanese) which is equivalent to Form 10-K in the US. The reliability of Yuho is ensured through statutory audits submitted to the Finance Bureau of the Ministry of Finance. Especially, the explanatory variables (1) to (4) are listed at the beginning of Yuho in a common format, forming the core of the financial results.
  - II. Environmental impact data: environmental reports, ESG reports and/or integrated company reports of each company.

Then, consolidated data are examined because non-consolidated financial and environmental data are not disclosed in detail.

First, the linear regression model is as follows, where environmental impact of total CO_2 emissions (CO_2) is the dependent variable and each variable from (1) SAL to (7) TSR is placed as the explanatory variable.

$$Y\,(CO_2) = \alpha + \beta_1\,(SAL) + \varepsilon, \tag{1.1.1}$$

$$Y\,(CO_2) = \alpha + \beta_2\,(INC) + \varepsilon, \tag{1.2.1}$$

$$Y\,(CO_2) = \alpha + \beta_3\,(EPS) + \varepsilon, \tag{1.3.1}$$

$$Y\,(CO_2) = \alpha + \beta_4\,(SST) + \varepsilon, \tag{1.4.1}$$

$$Y\,(CO_2) = \alpha + \beta_5\,(PEQ) + \varepsilon, \tag{1.5.1}$$

$$Y\,(CO_2) = \alpha + \beta_6\,(RES) + \varepsilon, \tag{1.6.1}$$

$$Y\,(CO_2) = \alpha + \beta_7\,(TSR) + \varepsilon. \tag{1.7.1}$$

Table 1: Dependent and explanatory variables (abbreviation)

Dependent variables: 8	Explanatory variables: 7
1. Total CO_2 emissions (CO_2, thousand metric tons)	1. Net sales (SAL)
2. Scope 1 CO_2 emissions (SCP1)	2. Net income (INC)
3. Scope 2 CO_2 emissions (SCP2)	3. Earnings per share (EPS)
4. Scope 1+2 CO_2 emissions (SCP1+2)	4. Total assets (SST)
5. Scope 3 CO_2 emissions (SCP3)	5. Property, plant, and equipment (PEQ)
6. Electricity consumption (ELC, MWh)	6. Treasury stocks (RES)
7. Water consumption (AQU, m^3)	7. Total shareholders return (TSR) (1, 2, 4, 5, 6, 7): million JPY, (3): JPY
8. Industrial waste generation (WST, tons)	

The significance level of the P-value is set at 5% ($P < 0.05$). In principle, non-significant results are omitted in the text for brevity. α and ε indicate constant and error terms, respectively. The significance of the constant term is not considered. The data is presented to three digits after the decimal point to ensure rigor. If zero continues after the third digit (e.g., 0.0003666), it is not presented as 0.000, but as an exponent, 3.667E-04. The order of the equation numbers indicates the dependent variable, the explanatory variable, and the monomial/polynomial equation. 1.1.1 refers to the CO_2 - Net Sales - linear equation. Then, the order of the explanatory variables is the same as above, only replacing the dependent variable, while the formulas from Scope 1 CO_2 emissions (SCP1) in the dependent variable (2) to Scope 3 CO_2 emissions (SCP3) are omitted.

Next, the formulas for electricity consumption (ELC) are:

$$Y\,(ELC) = \alpha + \beta_1\,(SAL) + \varepsilon. \qquad (6.1.1)$$

omitted

$$Y\,(ELC) = \alpha + \beta_7\,(TSR) + \varepsilon. \qquad (6.7.1)$$

Moreover, the formulas for water consumption (AQU) are:

$$Y\,(AQU) = \alpha + \beta_1\,(SAL) + \varepsilon. \qquad (7.1.1)$$

omitted

$$Y\,(AQU) = \alpha + \beta_7\,(TSR) + \varepsilon. \qquad (7.7.1)$$

Furthermore, the formulas for industrial waste generation (WST) are:

$$Y\,(WST) = \alpha + \beta_1\,(SAL) + \varepsilon. \qquad (8.1.1)$$

omitted

$$Y\,(WST) = \alpha + \beta_7\,(TSR) + \varepsilon. \qquad (8.7.1)$$

The second is to examine the EKC hypothesis. The examples of the formula are:

$$Y\,(CO_2) = \alpha + \beta_{11}\,(SAL) + \beta_{12}\,(SAL)^2 + \varepsilon. \qquad (1.1.2)$$

omitted

$$Y\,(CO_2) = \alpha + \beta_{17}\,(TSR) + \beta_{72}\,(TSR)^2 + \varepsilon. \qquad (1.7.2)$$

The third is to verify whether or not an inverted N-shaped curve is established. The examples of the formula are:

$$Y\,(CO_2) = \alpha + \beta_{11}\,(SAL) + \beta_{12}\,(SAL)^2 + \beta_{13}\,(SAL)^3 + \varepsilon. \qquad (1.1.3)$$

omitted

$$Y\,(CO_2) = \alpha + \beta_{71}\,(TSR) + \beta_{72}\,(TSR)^2 + \beta_{73}\,(TSR)^3 + \varepsilon. \qquad (1.7.3)$$

3.2. Results

This study's findings are as follows. First, linear regression analysis reveals significant monotonic relationships in 18 cases in 2019, 27 in 2020 and 34 in 2021 out of the 112 cases tested, respectively, as seen in Table A2. The results illustrate a trend in which when financial performance expands, environmental impact increases.

More importantly, the regression analyses confirm the EKC hypothesis and an inverted N-shaped curve in 2019, 2020, and 2021, that is, in the years prior to the COVID-19 and even in the vortex. The quadratic regression analysis of the EKC hypothesis confirms the validity of 14 cases in 2019, 13 in 2020, and 14 in 2021. Further, the cubic regression analysis of the inverted N-shaped curve confirms the validity of four cases in 2019 and two cases in 2020 and 2021 (Table 2).

Especially, Figure 1 illustrates the explanatory variables (TSR (total shareholders return)/per person) on the X-axis, while the dependent variables (CO_2/per person) are on the Y-axis, revealing that the relationships depict inverted U-shaped curves with the turning points.

The four cases in which the EKC hypothesis was established with TSR are listed below.

- SCP3/pers (Scope 3 CO_2 emissions/per person)–TSR/pers in 2019
- CO_2/pers (total CO_2 emission)–TSR/pers in 2020
- SCP3/pers–TSR/pers in 2021
- CO_2/pers–TSR/pers EKC in 2021

2019

$$Y\,(SCP3/pers) = \alpha + \beta\,(TSR/pers) + \beta\,(TSR/pers)^2 + \varepsilon,$$

$$= -\,0.231 + 217.979(TSR/pers) - 6{,}227.433\,(TSR/pers)^2 + 0.490.$$

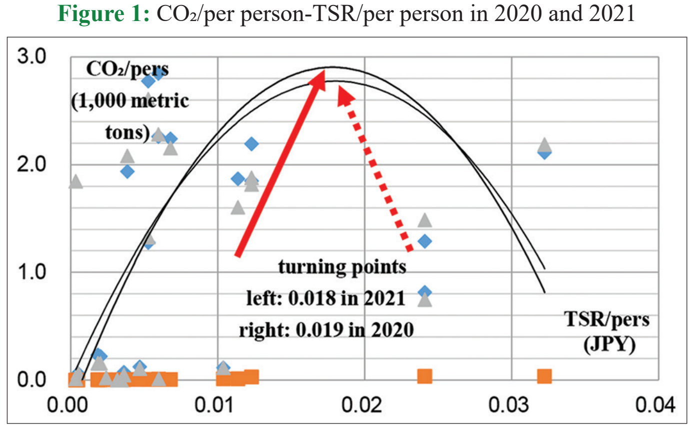
$$(p = 0.352) \qquad (0.002) \qquad (0.009)$$

Adj.-R^2 = 0.501, F = 9.022 (p = 0.003),

turning point: 0.0175.

2020

Figure 1: CO_2/per person-TSR/per person in 2020 and 2021



Sources: author's calculation

Table 2: Number of significant cases and percentage

year	1st	2nd	3rd
2019	18 (16.1)	14 (12.5)	4 (3.6)
2020	27 (24.1)	13 (11.6)	2 (1.8)
2021	34 (30.4)	14 (12.5)	2 (1.8)

Source: The author's calculations

$Y (CO_2/pers) = \alpha + \beta (TSR/pers) + \beta (TSR/pers)^2 + \varepsilon,$

$= 0.251 + 389.228(TSR/pers) – 9{,}985.570(TSR/pers)^2 + 1.859.$

$(p = 0.762)$ (0.039) (0.050)

$Adj.\text{-}R^2 = 0.146, F = 2.619 (p = 0.102),$

turning point: 0.019.

2021

$Y (SCP3/pers) = \alpha + \beta (TSR/pers) + \beta (TSR/pers)^2 + \varepsilon,$

$= - 0.114 + 190.060 (TSR/pers) - 5712.342 (RES)^2 + 0.700.$

$(p = 0.709)$ (0.006) (0.009)

$Adj.\text{-}R^2 = 0.240, F = 4.799 (p = 0.019),$

turning point: 0.017.

$Y (CO_2/pers) = \alpha + \beta (TSR/pers) + \beta (TSR/pers)^2 + \varepsilon,$

$= - 0.193 + 351.596(TSR/pers) – 9{,}946.117(TSR/pers)^2 + 1.627.$

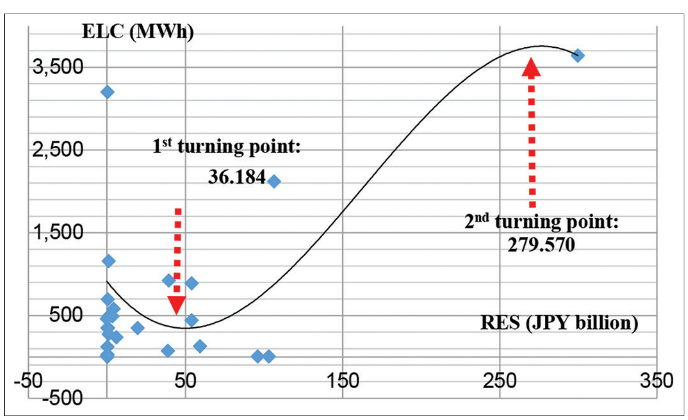
$(p = 0.792)$ (0.026) (0.049)

$Adj.\text{-}R^2 = 0.149, F = 3.094 (p = 0.065),$

turning point: 0.018.

Moreover, Figure 2 illustrates the explanatory variables (RES (treasury stocks)) on the X-axis, while the dependent variables (ELC (electricity consumption)) are on the Y-axis, revealing that the relationships depict an inverted N-shaped curve with the two turning points. Unlike in the EKC cases, no combination revealed a significant relationship with TSR in the inverted N-shaped curve. The following is the relationship between ELC and RES.

Figure 2: Electricity consumption (ELC)-treasury stocks (RES) in 2021



Sources: author's calculation

- ELC–RES

$Y (ELC) = \alpha + \beta (RES) + \beta_{32} (RES)^2 + \beta (RES)^3 + \varepsilon$

$= 1{,}002{,}164.598\text{-}52.548 (RES) + 7.260E\text{-}04 (RES)^2$

$(p = 0.005)$ (0.013) (0.003)

$- 1.731E\text{-}09 (RES)^3 + 1{,}259{,}648.567$

(0.005)

$Adj.\text{-}R^2 = 0.471, F = 8.727 (p = 4.769E\text{-}04),$

turning points: 36.184 and 279.,570

The explanatory variable for which the EKC hypothesis was most often established was SST (total assets), with five cases in 2019, five in 2020, and six in 2021. The inverted N-shaped curve also revealed that SST was the most common, with two cases in 2019, none in 2020, and one in 2021, as seen in Table A3.

However, the investment in total assets beyond the appropriate level can be a double-edged sword; environmental impacts will increase again when the appropriate level, which is indicated by the second turning point of the inverted N-shaped curve in Figure 3, is exceeded. In fact, the SST in which both are divided by persons and not divided recorded the largest number of eight cases in which the cubic term was positive, as presented in Table A5. The results imply that even if a company invests in eco-friendly buildings and factories, there is concern that overinvestment can increase the environmental impact.

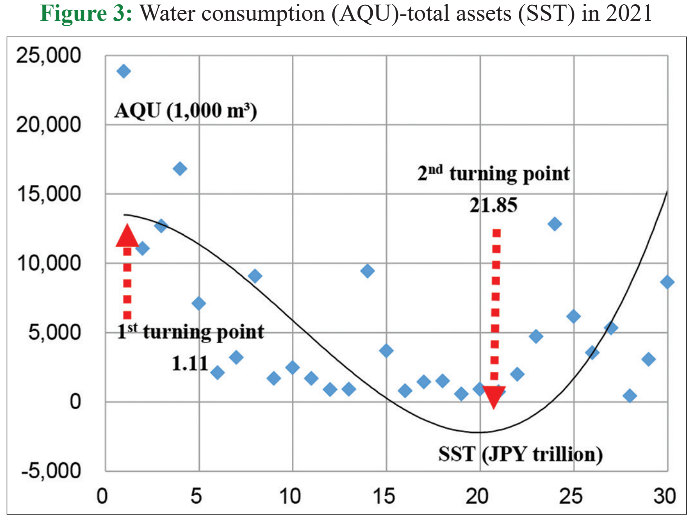
- AQU–SST

$Y (AQU) = \alpha + \beta(SST) + \beta (SST)^2 + \beta (SST)^3 + \varepsilon$

$= - 3.384E{+}06 + 3.381(SST)\text{-}1.1519E\text{-}07(SST)^2$

$(p = 0.402)$ (0.013) (0.031)

Figure 3: Water consumption (AQU)-total assets (SST) in 2021



Sources: Author's calculation

$+ 4.633E\text{-}16\ (SST)^3 + 1.382E{+}07$

(0.034)

Adj.-$R^2 = 0.115$*, F = 2.518 (p = 0.076),*

turning points: 1.113E+07 and 2.185+E08.

TSR accounted for only one significant case of the EKC hypothesis in 2019, one in 2020, and two in 2021. Moreover, there was no significant combination of TSR in inverted N-shaped curves. TSR seems less important than SST in terms of the number of significant cases, but it is more important in two aspects.

First, TSR has no significant cases in which cubic terms are positive, while SST has eight cases, as presented in Table A5. This means that TSR has no or small concerns about increasing environmental impacts due to overinvestment.

Second, five firms that exceeded the TSR threshold above the turning points of the JPY 0.018-0.019 level in the EKC hypothesis in Table 3 are not among the top-ranked firms in net sales, number of customers, and total assets. This can be a goal for other public utilities in the middle and lower rankings.

Furthermore, the emergence of the turning points in Figure 1 indicates the birth of the growth and environmental impact decoupling. The increasing TSR to the thresholds, that is, JPY 0.018-0.019 in the EKC, can serve as guidelines or benchmarks for decoupling. Therefore, TSR can be the key to establishing the EKC hypothesis, that is, realizing environmental conservation.

3.3. Discussion

The author discusses deciding factors of the significance of the results analyzed. First, the results of the linear regression indicate that the environmental impacts increase as the financial scales increase. For example, the significant results for 2019 demonstrate that CO_2 (total CO_2 emissions) increases as INC (net income) increases (1-2). Similarly, ELC (electricity consumption) increases as SAL (net sales) increases (7-1). These results indicate that emissions and consumption increase with growth.

Table 3: The major shareholders of UNPRI signatories in the public utilities as of March 2022

Company	Top ten shareholders - investment ratio: %
Chubu Electric power	3 Meiji Yasuda Life Insurance 4.95 4 Nippon Life Insurance 3.10 6 JP Morgan 1.19
Kansai Electric power	4 Nippon Life Insurance 3.07
Okinawa Electric power	7 Meiji Yasuda Life Insurance 2.32 8 Nippon Life Insurance 1.92 10 Mitsubishi UFJ Trust and Banking 1.46
Saibu gas	2 Nippon Life Insurance 6.64 9 Sumitomo Mitsui Trust Bank 2.29
Toho gas	2 Nippon Life Insurance 5.57 6 Dai-ichi Life Insurance 2.28 8 Meiji Yasuda Life Insurance 1.75

Source: Annual Securities Reports 2022 of each company

Of course, total CO_2 emissions include external factors that cannot be solved by the company's own efforts. This is because the total CO_2 emissions include various activities from upstream to downstream of the company, and there are extenuating circumstances in which insufficient reduction efforts by business partners, in addition to the market expansion of demand increase.

However, the deciding factors that contribute to the establishment of the EKC hypothesis and the inverted N-shaped curve are the result of the interaction of the following five points, which have been more encouraged and promoted in Japan in recent years:

1. Regulatory reforms such as energy market opening;
2. Investors' emphasis on environment, society, and governance (ESG);
3. Guidelines and assessments by the economic organizations, rating agencies, and environmental non-profit groups;
4. Citizens' professional ethics, and willingness for environmental conservation and social contribution;
5. Endogenous efforts by the public utilities as members of society.

The first factor is regulatory reforms such as the energy market opening in Japan. The liberalization of the domestic electricity and gas markets has progressed in stages since 2000, reaching the full opening of the residential power market in 2016 and the gas market in 2017. The liberalization has further compelled traditional power monopolies such as TEPCO to compete for customers who value environmental conservation beyond the previous monopolistic and regional jurisdictions and industrial segments. Telecommunications carriers and gas companies have entered the electricity power market. For example, Softbank, the third largest telecommunications company in terms of the number of customers after Nippon Telegraph and Telephone (NTT) and KDDI, has established, SB Energy, a power subsidiary that generates electricity exclusively from renewable energy sources. Moreover, in cooperation with Tokyo Gas and Osaka Gas beyond business boundaries, NTT has established Ennet—a power subsidiary that utilizes a gas turbine combined power generation system with relatively low CO_2 emissions based on state-of-the-art technology. As of June 2022, new entrants accounted for 19.9% and 17.5% of total electricity and gas sales volume, respectively (Ministry of Economy, Trade and Industry, 2022). Thus, market liberalization requires companies to develop environmentally-oriented strategies.

The second factor is the increased investors' emphasis on ESG. It has been functioning as the compelling or driving force to advance public utilities' environmental conservation activities, especially through financing requirements, such as loans and underwriting of securities and bonds.

Among ESG initiatives, the impact of the United Nations' Principles for Responsible Investment (PRI) has been increasing (PRI, 2022). Signatory investors are bound by the Six Principles. For examples, "We (signatory investors) will incorporate ESG issues into investment analysis and decision-making processes" (Principle 1). "We will seek appropriate disclosure on ESG issues by the entities in which we invest" (Principle 3). Consequently, the principles require signatory investors such as life and nonlife insurance companies, asset managers, and pension funds listed in Table 3 to make ESG-conscious investment and holding decisions, disclose information to their investees, and even obligate investors themselves to disclose information.

The number of signatory investors increased globally from 63 in 2006 (start year) to 3,404 in the end of 2021, and 5,237 as of October 2022 and the total amount of assets under management increased from USD 6.5 trillion in 2006 to 121 trillion as of October 2022. The number of signatory companies headquartered in Japan has been also increasing every year, reaching 118.

Table 3 lists the major shareholders with UNPRI signatures in five public utilities that exceeded the TSR threshold. The table indicates that these signatories exercise a certain degree of influence in ESG management.

In addition, the amount of issuance of environment-related bonds, known as green bonds, has increased year by year in Japan, as presented in Table 4 by the Japan Securities Dealers Association (JSDE, 2022).

The amount of issuance (b) only by the 43 utilities in 2021 increased by 5.8 times from 2019, while that of issuance of (a) overall domestic green bonds increased just by 1.6 times. Of course, some of the 43 firms did not issue green bonds, but the 43 exceeded Japan as a whole in the growth rate of green bond issuance, which suggests that the funds contributed to the EKC hypothesis through investment in environmental conservation.

Shareholders' proposals have also begun to exercise influence. For instance, at the 2022 shareholders' meeting of Electric Power Development Inc., the proposal was rejected, but a provision was proposed as an amendment to the articles of incorporation that the company shall formulate and publish a business plan for the reduction of greenhouse gas emissions (Electric Power Development, 2022c). Thus, management is increasingly compelled to consider ESG-related proposals.

The third factor is guidelines and assessments by economic organizations, rating agencies, and environmental nonprofit groups. The Keidanren (Japan Business Federation)'s ESG-oriented guidelines should be mentioned. Keidanren is one of the most influential economic organizations in Japan. As of April 1, 2022, a total of 1,652 Japanese listed companies, such as Toyota Motor Corporation and 40 of the 43 public utilities belong to the Keidanren. Moreover, it makes policy recommendations on economic and environment issues and provides corporate guidelines with binding force, including the expulsion clause for members.

Table 4: Amounts of issuance: (a) overall domestic green bonds and (b) green bonds issued only by the 43 utilities from 2016 to 2021 (JPY billion)

Classification	16	17	18	19	20	21
Overall	10	66	234	712	1,374	1,831
Only by the utilities	0	20	35	117	259	793

Source: JSDE 2022

In particular, Keidanren revised its Charter of Corporate Behavior for the achievement of the Sustainable Development Goals (SDGs) in 2017 (Keidanren, 2017). The Charter says, "As a good corporate citizen, we (member companies) will actively participate in society and contribute to its development." "We promote initiatives for social responsibility through ESG-conscious management." "We will act toward the achievement of a sustainable society." The Keidanren has also continued to share ESG best practices. Thus, the public utilities, while competing, have been sharing ESG-related knowledge with rivals.

Behind the Keidanren Charter, there are widely shared Japanese views that "a corporation belongs not so much to its shareholders as to everyone involved with it, including investors, executives, employees, customers, business partners, and local communities," and "even though they are private companies, they should conduct as respectful legal entities or members of society." These views shared in Japan affect the "(5) endogenous efforts of firms," which will be discussed later.

Then, another initiatives and ratings below-mentioned are also relatively large and influential.

1. Task Force on Climate-related Financial Disclosures (TCFD): This task force examines and recommends climate-related information disclosure and targets; 4,024 in global total and 1,137 in Japan as of November 2022. Of the 43 public utilities, 40 endorsed the TCFD
2. CDP (formerly known as Carbon Disclosure Project): Advocates disclosing information such as climate change mitigation, water security, and forests while maintaining consistency with the TCFD, publishing a rating with the highest grade of A; 13,189 and 427 in the end of 2021
3. Morgan Stanley Capital International (MSCI) ESG Ratings: An index of global research affiliated with Morgan Stanley; about 2,900.

Table 5 presents the signatures and ratings of the five utilities that exceeded the TSR threshold in Table 3 and the top-ranked six utilities by net sales in 2021 in each of the utility sectors in telecommunications, airlines, railways, electricity, gas, and postal services that have not exceeded the threshold yet.

A yearly featured article "The SDG Company Ranking" published by Toyo Keizai—one of the best-selling weekly economic magazines—is also influential. Toyo Keizai (2021) placed KDDI, the second largest telecommunications company in Japan in terms of the number of customers, in the 11th position, while NTT, the largest one, is ranked 21st. The result indicates that rivals are competing not only in financial performance but also in non-financial environmental scores. Similarly, among power and gas companies, Kansai Electric Power is ranked 58th, while Osaka Gas is ranked 60th, indicating that the two companies, both headquartered in Osaka City, are competing. Although the ESG/SDGs scores are arbitrary, as mentioned in Section 2.2, and it is inappropriate to conduct a purely academic analysis of the scores, a good score contributes to improving companies' external image and is advantageous in recruiting human resources.

Table 5: The public utilities' signatures (☑) and ratings

Company name	TCFD	CDP		MSCI
		Climate	Water	
Chubu electric power	☑	A-	B	BB Average
Kansai electric power	☑	A	F	BB Average
Okinawa electric power	☑	B	F	NA
Saibu gas	☑	NA	NA	NA
Toho gas	☑	A-	A-	NA
Top-ranked utilities, though not-exceed				
Nippon telegraph and telephone (NTT)	☑	A-	NA	A average
ANA	☑	A	NA	A average
East Japan railway	☑	A-	F	A average
Tokyo electric power (TEPCO)	☑	B	A-	CCC laggard
Tokyo gas	☑	A-	F	AA leader
Japan post	☑	A-	NA	BBB average

Sources: Each website as of December 2022

Especially, disclosure is important in scoring. Without appropriate disclosure of ESG information, the public utilities face challenges in raising funds through the issuance of bonds and securities and bank financing with more favorable terms, and recruiting human resources. In addition, disclosure requires the formulation and execution of corporate strategies that are worthy of disclosure, and the promotion of ESG-activities, such as participation and signature on ESG initiatives. Furthermore, data is disclosed on sponsoring organizations' websites regarding whether the public utilities signify and the attending ratings. As a result, the public utilities are driven to compete with rivals in terms of disclosure.

The fourth factor is the further rise in citizens' professional ethics and willingness for environmental conservation and social contribution. The increased trends are illustrated by Nippon Hoso Kyokai (NHK) Broadcasting Culture Research Institute (2018). NHK is a public broadcaster in Japan, and the 5-year periodic opinion surveys by NHK's affiliate institute are the longest-running in Japan since 1973. To the question, "What is your ideal job?" the answer "a job that contributes to society" increased from 12.2% in 1988 to 21.0% in 2018. The number of "Yes" responses to the question "Do you want to contribute to Japan?" increased to 70.3% from 65.7% in the previous survey. In each of the surveys, the total number of samples is 5,400, with 3,853 valid responses (71.4%) in June 1988 and 2,751 valid responses (50.9%) in June 2018.

Moreover, firms that emphasize ESG have an advantage in recruiting over other firms. A Japanese major recruiting firm Disco's survey (2022), targeting university students, concluded that a company's social contribution, including environmental conservation, influences its job selection (number of respondents: 1,055; response rate: unpublished). Regarding the question that requires the students to choose the most important factor in selecting a company, the largest response rate was "high social contribution" at 29.4% in 2019 and 30.0% in 2020. In addition, when asked "Does a company's positive approach to ESG or SDGs affect your choice of the company?" 7.3% chose "very influential" and 33.9% chose "influential" (41.2% in total). Thus, one of the deciding factors is a rise in citizens' professional ethics and willingness for environmental conservation and social contribution.

The fifth and final factor is the endogenous efforts by public utilities as members of society. All the corporations in the first place, whether they are institutional investors or public utilities, are a collection of citizens. As citizens' willingness for environmental conservation and social contribution increases, discussions on ESG-oriented issues within public utilities will naturally increase. Then, both management and employees will take more ESG-oriented strategies and actions. For example, they tend to shift from prioritizing sales and name recognition in the growth phase to emphasizing ESG activities in the mature phase. They also tend to introduce expensive, high-performance, and state-of-the-art technologies and equipment based on elevated access to financing in more favorable conditions due to increased credibility and name recognition.

For example, telecommunications companies are working to reduce the power consumption of their data centers. Power Usage Effectiveness (PUE) indicates the power consumption efficiency of a data center, and the closer it is to 1.0, the better it is. NTT Data, one of the most influential subsidiaries of NTT, announced (NTT Data, 2022) that NTT achieved an average of 1.2 in 2021 and a maximum of 1.07 in 2022, compared with an average of 1.91 in 2015. Further, NTT (2023) has announced the joint development with KDDI, a competitor of NTT, of a sixth-generation mobile communications system (6G, or Beyond 5G), which will reduce power consumption by one hundredth. Z Holdings, another telecommunication company, also announced the construction of data centers with a PUE of less than 1.5 based on renewable energy sources through a green bond of JPY 20 billion ($136 million) in 2021. Hence, the EKC hypothesis was established as a result of the interaction of the five points, which have been more encouraged and promoted in Japan in recent years.

Next, it is necessary to investigate the reasons certain combinations are significant in the EKC hypothesis and the inverted N-shaped curve, even if it is difficult to prove all the combinations mathematically. For example, in the combination of CO_2 and TSR, the reduction of CO_2 emissions is one of the easy-to-understand goals that appeal to investors and potential job applicants. TSR is also shareholder-oriented. Among the explanatory variables (1)-(8), significance is established for the ELC in the 14 largest combinations in Table A3. The reduction of electricity consumption is also an easy-to-understand goal that are readily to initiate through installing LEDs, motion sensors, wireless switches.

4. CONCLUSION AND IMPLICATIONS

The regression analyses confirmed the EKC hypothesis and the existence of an inverted N-shaped curve in 2019, 2020, and 2021. The results revealed that the quadratic regression analysis of the EKC hypothesis validates 14 cases (12.5%) in 2019, 13 (11.6%) in 2020, and 14 (12.5%) in 2021. Furthermore, the cubic regression analysis of the inverted N-shaped curve validates four cases (3.6%) in 2019 and two cases (1.8%) in 2020 and 2021 each in terms of the financial performance and environmental impacts of the 43 public utilities listed on the Tokyo Stock Exchange.

Moreover, the deciding factors for the EKC hypothesis and inverted N-shaped curve were the result of the interaction of the following five points, which have been encouraged and promoted in Japan in recent years: (1) regulatory reforms such as energy market opening; (2) investors' emphasis on ESG; (3) guidelines and assessments by economic organizations, rating agencies, and environmental nonprofit groups; (4) citizens' professional ethics and willingness for environmental conservation and social contribution; and (5) endogenous efforts by the public utilities as members of society.

Of course, the following issues remain to be examined. It is necessary to consider further why only some cases in the EKC hypothesis and in the inverted N-shaped test are significant, whereas others are not. Long-term verification is also needed because environmental statistics are subject to revision. Additionally, the public utilities themselves have been facing various challenges in abusing monopolistic market power, improving corporate governance structure, protecting personal information, saving energies, and paying fair taxation.

However, it is implied that the emergence of the turning points in Figures 1 and 2 indicates the germination or beginning of the decoupling of growth and environmental impact. Hence, increasing TSR to the thresholds, that is, JPY 0.018-0.019 in the EKC can serve as guidelines or benchmarks for public utilities that have not reached the above levels for the decoupling. As the sales and emissions of public utilities studied in this paper correspond to those of a single country, ESG-oriented management and increasing TSR to the thresholds can eventually contribute to domestic and global environmental conservation.

Moreover, an approach that focuses on ESG and TSR demonstrated in this paper can contribute to the expansion of the academic frontiers of environmental economics and industrial organization theory. Therefore, it is recommended that the academic community keep exploring the relationship between growth and environmental conservation.

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Table A1: Company names of the 43 public utilities

Electric power and gas - 18
Electric Power (11)
Chubu Electric Power, Chugoku Electric Power,
Electric Power Development (J-Power),
Hokkaido Electric Power, Hokuriku Electric Power,
Kansai Electric Power, Kyushu Electric Power,
Okinawa Electric Power, Shikoku Electric Power, Tohoku Electric Power, Tokyo Electric Power
Gas (7)
Hokkaido Gas*, Shizuoka Gas*, Toho Gas, Tokyo Gas, Osaka Gas, Hiroshima Gas*, Saibu Gas
Transport - 19
Airlines (2)
ANA Holdings, Japan Airlines
Railway (17)
East Japan Railway, Central Japan Railway,
Hankyu Hanshin Holdings, Keihan Holdings, Keikyu, Keisei Electric Railway, Keio, Kintetsu Group Holdings, Kyushu Railway, Nankai Electric Railway, Nishi - Nippon Railroad, Odakyu Electric Railway, Seibu Holdings, Sotetsu Holdings, Tobu Railway, Tokyu, West Japan Railway
Telecommunications and Postal Services - 6
Telecommunications (5)
KDDI, Nippon Telegraph and Telephone (NTT), SoftBank, Rakuten Group, Z Holdings
Postal services (1)
Japan Post Holdings

Company, Corporation, etc., are omitted for simplicity. Except for the three marked with an asterisk (*), 40 companies have signed the TFCD. The names and figures of the smallest and largest firms in terms of staff and sales in 2021 are as follows: Hokkaido Gas–1,459 persons and NTT–333,840 persons, Hiroshima Gas–USD 431 million and NTT–USD 91 billion

Table A2: Significant combinations of dependent and explanatory variables of linear model

Variables	Constant	(p)	x	(p)	Standard errors	Adj.-R_2	F	(p)
2019								
(1-1) CO_2/pers-SAL/pers	−1.343	0.132	0.039	0.001	1.575	0.432	14.686	0.001
(1-2) CO_2-INC	−23.719	0.978	0.038	0.027	947.559	0.996	557.725	0.027
(1-3) CO_2/pers-EPS/pers	0.844	0.139	93.213	0.036	1.883	0.188	5.170	0.036
(1-5) CO_2-PEQ	−5,314.261	0.137	0.004	0.037	1,306.632	0.993	292.835	0.037
(1-7) CO_2-RES	−132.676	0.903	0.043	0.034	1,179.628	0.994	359.513	0.034
(2-6) SCP2/pers- RES/pers	−0.090	0.503	0.169	0.021	0.546	0.148	6.027	0.021
(3-1) SCP1+2/pers-SAL/pers	−0.390	0.464	0.014	0.050	1.376	0.099	4.203	0.050
(4-1) SCP3/pers-SAL/pers	−0.606	0.090	0.017	0.001	0.500	0.481	15.809	0.001
(4-3) SCP3-EPS	0.332	0.081	35.717	0.014	0.582	0.296	7.739	0.014
(4-5) SCP3-PEQ	3,120.571	0.704	0.006	0.038	24,688.074	0.184	5.063	0.038
(4-5) SCP3/pers-PEQ/pers	0.053	0.856	0.009	0.033	0.612	0.220	5.503	0.033
(4-7) SCP3/pers-TSR	0.301	0.156	48.453	0.029	0.608	0.232	5.835	0.029
(7-1) ELC-SAL	448,648.580	0.175	0.287	0.003	1.362E+06	0.291	11.269	0.003
(7-2) ELC-INC	1.021E+06	0.002	1.465	0.020	1.471E+06	0.173	6.229	0.020
(7-3) ELC-EPS	700,019.254	0.051	1,647.846	0.047	1.518E+06	0.119	4.384	0.047
(7-5) ELC- PEQ	−39,722.953	0.870	0.615	2.535E-07	939,260.987	0.663	50.174	2.535E-07
(7-6) ELC-RES	784,687.678	0.023	3.147	0.049	1.521E+06	0.116	4.283	0.049
2020								
(1-1) CO_2/pers-SAL/pers	−1.485	0.037	0.045	1.215E-04	1.356	0.525	23.143	1.215E-04
(1-5) CO_2/pers-PEQ/pers	−1.107	0.077	0.036	1.210E-04	1.356	0.526	23.161	1.210E-04
(2-1) SCP1/pers-SAL/pers	−0.364	0.331	0.015	0.010	1.173	0.162	7.569	0.010
(2-3) SCP1-EPS	0.555	0.010	32.192	0.020	1.196	0.128	6.003	0.020
(2-5) SCP1/pers-PEQ/pers	−0.508	0.200	0.014	0.005	1.154	0.188	8.863	0.005
(3-1) SCP2-SAL	80.280	0.637	2.213E-04	7.475E-05	818.625	0.364	20.454	7.475E-05
(3-4) SCP2/pers-SST/pers	0.005	0.073	3.198E-05	1.013E-08	0.013	0.624	57.453	1.013E-08
(3-5) SCP2-PEQ	−243.282	0.113	4.082E-04	1.781E-08	639.981	0.611	54.461	1.781E-08
(3-5) SCP2/pers-PEQ/pers	−0.001	0.913	2.039E-04	0.021	0.021	0.126	5.889	0.021
(3-6) SCP2-RES	368.329	0.043	0.002	0.027	966.260	0.114	5.367	0.027
(4-1) SCP1+2/pers-SAL/pers	−0.389	0.298	0.014	0.012	1.168	0.159	7.050	0.012
(4-3) SCP1+2/pers-EPS/pers	0.572	0.014	38.015	0.034	1.202	0.109	4.901	0.034
(4-5) SCP1+2/pers-PEQ/pers	−0.487	0.222	0.013	0.011	1.162	0.167	7.414	0.011
(5-3) SCP3/pers-EPS/pers	0.619	0.000	19.155	0.042	0.653	0.157	4.734	0.042
(5-5) SCP3-PEQ	4,107.944	0.519	0.006	0.017	21,694.263	0.208	6.790	0.017
(5-5) SCP3/pers-PEQ/pers	−0.031	0.900	0.010	0.004	0.583	0.330	10.832	0.004
(6-1) ELC- SAL	581,857.623	0.067	0.271	0.005	1.448E+06	0.223	9.336	0.005
(6-5) ELC-PEQ	−100,699.637	0.585	0.721	8.602E-11	777,682.583	0.775	101.022	8.602E-11

(Contd...)

Table A2: ***(Continued)***

Variables	Constant	(p)	x	(p)	Standard errors	Adj.-R_2	F	(p)
				2020				
(6-5) ELC/pers-PEQ/pers	10.303	0.233	0.420	0.003	23.483	0.243	10.302	0.003
(6-7) ELC- RES	817,281.805	0.012	3.090	0.049	1.558E+06	0.100	4.239	0.049
(6-8) ELC/pers-TSR/pers	22.633	0.001	1,664.225	0.005	23.585	0.233	9.490	0.005
(7-1) AQU/pers-SAL/pers	−199.191	0.102	6.006	0.001	386.112	0.234	12.024	0.001
(7-4) AQU/per-SST/pers	48.521	0.516	0.369	0.006	400.283	0.177	8.753	0.006
(7-5) AQU- PEQ	369,392.611	0.902	2.340	0.048	1.344E+07	0.082	4.205	0.048
(7-5) AQU/pers-PEQ/pers	−113.764	0.403	3.827	0.030	417.997	0.103	5.123	0.030
(7-8) AQU/pers-TSR/pers	−35.081	0.705	18624.232	0.008	406.361	0.166	7.948	0.008
(8-1) WST/pers -SAL/pers	−10.957	0.478	0.449	0.043	47.328	0.091	4.420	0.043
				2021				
	Constant	**(p)**	**x**	**(p)**	**St. errors**	**Adj.-R_2**	**F**	**(p)**
(1-2) CO_2/pers-Inc/pers	1.060	0.003	0.196	0.004	1.535	0.283	10.477	0.004
(1-3) CO_2/pers-EPS/pers	1.064	0.001	98.107	5.208E-05	1.287	0.495	24.557	5.208E-05
(1-5) CO_2/pers-PEQ/pers	−0.885	0.101	0.032	4.048E-05	1.274	0.506	25.575	4.048E-05
(2-1) SCP1/pers-SAL/pers	−0.472	0.207	0.016	0.004	1.105	0.208	9.672	0.004
(2-2) SCP1/pers-INC/pers	0.327	0.131	0.097	0.019	1.156	0.133	6.073	0.019
(2-3) SCP1/pers-EPS/pers	0.276	0.131	64.950	1.105E-04	0.994	0.358	19.416	1.105E-04
(2-5) SCP1/pers21-PEQ/pers	−0.476	0.192	0.014	0.003	1.095	0.221	10.386	0.003
(3-1) SCP2-SAL	194.384	0.368	1.905E-04	0.004	997.542	0.210	9.757	0.004
(3-1) SCP2/pers-SAL/pers	−0.001	0.910	2.892E-04	0.030	0.028	0.111	5.133	0.030
(3-3) SCP2-EPS	−50.270	0.817	3.622E-04	1.583E-04	908.693	0.344	18.322	1.583E-04
(4-1) SCP1+2/pers-SAL/pers	−0.473	0.202	0.016	0.003	1.095	0.218	10.208	0.003
(3-2) SCP1+2/pers-INC/pers	0.342	0.113	0.097	0.018	1.151	0.136	6.208	0.018
(4-3) SCP1+2/pers-EPS/pers	0.293	0.108	64.875	1.074E-04	0.991	0.359	19.504	1.074E-04
(4-4) SCP1+2/pers-PEQ/pers	−0.473	0.191	0.014	0.002	1.086	0.230	10.857	0.002
(5-1) SCP3/pers-SAL/pers	−0.494	0.029	0.017	1.720E-06	0.494	0.622	40.463	1.720E-06
(5-2) SCP3/pers-INC/pers	0.596	0.001	0.062	0.046	0.751	0.125	4.441	0.046
(5-3) SCP3/pers-EPS/pers	0.608	0.001	27.992	0.020	0.728	0.180	6.259	0.020
(5-4) SCP3-PEQ	4,736.519	0.431	0.005	0.029	20,810.957	0.155	5.405	0.029
(5-4) SCP3/pers-PEQ/pers	−0.051	0.857	0.011	0.005	0.690	0.262	9.523	0.005
(6-1) ELC-SAL	480,843.594	0.166	0.306	0.003	1.472E+06	0.278	11.016	0.003
(6-2) ELC-INC	871,063.226	0.003	3.136	2.016E-04	1.333E+06	0.408	18.910	2.016E-04
(6-2) ELC/pers-INC/pers	24.518	0.000	1.833	0.047	20.870	0.114	4.352	0.047
(6-5) ELC-PEQ	338,663.059	0.361	0.499	0.003	1.476E+06	0.274	10.819	0.003
(6-6) ELC-RES	549,376.073	0.108	12.917	0.003	1.482E+06	0.269	10.553	0.003
(7-1) AQU/pers-SAL/pers	−340.610	0.031	9.891	6.833E-05	484.729	0.359	20.563	6.833E-05
(7-2) AQU/pers-INC/pers	163.891	0.122	40.131	0.049	579.617	0.083	4.160	0.049
(7-3) AQU/pers-EPS/pers	153.359	0.136	19051.543	0.019	565.969	0.126	6.023	0.019
	Constant	**(p)**	**x**	**(p)**	**St. errors**	**Adj.-R_2**	**F**	**(p)**
(7-5) AQU-PEQ	636,048.040	0.844	2.680	0.045	1.404E+07	0.087	4.325	0.045
(7-5) AQU/pers-PEQ/pers	−267.542	0.113	7.566	0.001	521.589	0.257	13.124	0.001
(7-8) AQU/pers-TSR/per	25.135	0.857	28277.947	0.039	576.052	0.094	4.634	0.039
(8-1) WST/per-SAL/pers	-20.565	0.223	0.614	0.010	46.890	0.186	7.609	0.010
(8-2) WST/pers-INC/pers	8.384	0.359	4.883	0.005	45.907	0.219	9.150	0.005
(8-3) WST/pers-EPS/pers	5.806	0.469	2505.307	1.257E-04	40.483	0.393	19.770	1.257E-04
(8-5) WST/pers-PEQ/per	-17.606	0.330	0.490	0.027	48.388	0.133	5.437	0.027

Sources: Author's calculation based on the environmental reports/ESG data of each company

Table A3: Significant combinations of dependent and explanatory variables of EKC and inverted-N shaped curve

Dependent	2019		2020		2021		Subtotal
	Explanatory		Explanatory		Explanatory		
	EKC	inv.-N shaped	EKC	inv.-N shaped	EKC	inv.-N shaped	
(1) CO_2			SAL		SAL		SAL 2
CO_2/pers			SST/pers, TSR/pers		SST/pers, TSR/pers		SST/pers 2 TSR/pers 2
(2) SCP1							
SCP1/pers	SST/pers, PEQ/pers				INC/pers		INC/pers 1, SST/pers 1 PEQ/pers 1
(3) SCP2		EPS	SST		SAL, SST		SAL 1, SST 2, EPS 1
SCP2/pers	SST/pers	SST/pers					SST/pers 2
(4) SCP1+2							
SCP1+2/pers	SST/pers				SST/pers		SST/pers 2
(5) SCP3	SAL	PEQ	SAL, SST	PEQ	SAL		SAL 3, SST 1, PEQ 2
SCP3/pers	TSR/pers		INC/pers, EPS/pers		TSR/pers		INC/pers 1, EPS/pers 1 TSR/pers 2,
(6) ELC	SAL, SST, EPS, RES		SST, RES	INC	SST	RES	SAL 1, INC 1, SST 3 EPS 1, RES 3,
ELC/pers	EPS/pers, PEQ/pers		SAL, SST, PEQ				SAL 1, SST 1, EPS/pers 1 PEQ 1, PEQ/ pers 1
(7) AQU					SAL, PEQ		SAL 1, PEQ 1
AQU/pers					SST/pers		SST/pers 1
(8) WST							
WST/pers	SST/pers, PEQ/pers	SST/pers			SST/pers	SST/pers	SST/pers 4 PEQ/pers 1
▪ Subtotal	▪ SAL 2 ▪ ESP 1 ▪ EPS/pers 1 ▪ SST 1 ▪ SST/pers 4 ▪PEQ/pers 3 ▪ RES 1 ▪ TSR/pers 1	▪ EPS 1 ▪ SST/pers 2 ▪ PEQ 1	▪ SAL 3 ▪ INC/pers 1 ▪ EPS/pers 1 ▪ SST 4 ▪ SST/pers 1 ▪ PEQ 1 ▪ RES 1 ▪ TSR/pers 1	▪ INC 1 ▪ PEQ 1	▪ SAL 4 ▪ INC/pers 1 ▪ SST 2 ▪ SST/pers 4 ▪ PEQ 1 ▪ TSR/pers 2	▪ SST/ pers 1 ▪ RES 1	
Total	14	4	13	2	14	2	

Sources: author's calculation based on the environmental reports/ESG data of each company. Blank columns indicate that there are no significant combinations. For example, in 2019, no explanatory variables are significant in combination with CO_2. However, SCP1/pers are significant with SST/pers and PEQ/pers

Table A4: Significant combinations of dependent and explanatory variables of EKC and inverted-N shaped curve (negative: β<0)

Variables	Constant	(p)	x	(p)	x²	(p)	x³	(p)	Standard errors	Adj.-R₂	F	(p)	1st turning points	2nd turning points
2019														
(2-4) SCP1/ pers-SST/pers	−0.627	0.225	0.008	0.025	−6.361E-06	0.038			1.284	0.112	2.822	0.077	630.097	
(2-5) SCP1/ pers-PEQ/pers	−0.543	0.306	0.016	0.041	−2.308E-05	0.045			1.305	0.083	2.304	0.119	356.328	
(3-4) SCP2/ pers-SST/pers	−0.367	0.100	0.004	0.018	−2.739E-06	0.037			0.549	0.139	3.340	0.051	666.291	
(4-4) SCP1+2/ pers-SST/pers	−0.993	0.050	0.012	0.001	−9.100E-06	0.003			1.234	0.276	6.529	0.005	640.989	
(5-1) SCP3-SAL	−20,535.531	0.016	0.023	3.886E-05	−1.398E-16	7.305E-05			16,804.766	0.622	15.809	1.625E-04	8.155E+13	
(5-7) SCP3/ pers-TSR/pers	−0.231	0.352	217.979	0.002	−6227.423	0.009			0.490	0.501	9.022	0.003	0.018	
(6-1) ELC-SAL	69,860.215	0.856	0.658	0.010	−2.750E-15	0.104			1.312E+06	0.342	7.508	0.003	1.196E+14	
(6-4) ELC-SST	9,534.539	0.965	0.290	2.982E-08	−1.015E-09	2.554E-08			847,033.811	0.726	34.103	1.317E-07	1.430E+08	
(6-3) ELC-EPS	−391,290.763	0.403	10,916.146	0.002	−4.569	0.005			1.305E+06	0.349	7.711	0.003	1,194.682	
(6-3) ELC/ pers-EPS/pers	23.773	4.482E-04	991.398	0.020	−6958.9771	0.013			21.520	0.172	3.590	0.044	0.071	
(6-5) ELC/ pers-PEQ/pers	5.185	0.530	0.544	0.001	−7.380E-04	0.002			19.383	0.328	7.099	0.004	368.343	
(6-6) ELC-RES	302,662.793	0.332	23.570	0.001	−2.677E-05	0.002			1.268E+06	0.386	8.847	0.001	440,217.493	
(8-4) WST/ pers-SST/pers	−39.227	0.034	0.477	0.001	−3.743E-04	0.002			43.104	0.256	6.324	0.005	636.863	
(8-5) WST/ pers-PEQ/pers	−29.363	0.151	0.781	0.014	−0.001	0.015			46.459	0.135	3.425	0.046	359.298	
(3-4) SCP2/ pers-SST/pers	0.908	0.004	−0.015	3.714E-04	5.529E-05	3.228E-05	−3.687E-08	1.605E-05	0.388	0.569	13.739	1.453E-05	136.746	9.998E+02
(3-3) SCP2-EPS	14,098.602	0.004	−138.970	0.010	0.2997	0.025	−1.155E-04	0.0330	10,940.627	0.148	2.674	0.068	231.842	1.729E+03
(5-5) SCP3-PEQ	21,531.980	0.050	−0.035	0.014	1.653E-08	0.001	−1.387E-15	4.810E-04	16,670.749	0.628	11.129	4.231E-04	1.062E+06	7.944E+06
(8-4) WST/pers -SST/pers	69.548	0.013	−1.232	0.002	5.515E-03	1.002E-04	−3.869E-06	4.195E-05	32.343	0.581	15.325	4.316E-06	111.707	9.504E+02
2020														
(1-1) CO_2-SAL	−2,077.228	0.779	0.022	0.003	−1.745E-09	0.003			16,239.600	0.333	5.993	0.010	6.325E+06	
(1-4) CO_2/pers -SST/pers	−0.398	0.647	0.013	0.025	−1.047E-05	0.023			1.789	0.174	3.108	0.069	620.354	
(1-7) CO_2/pers -TSR/pers	−0.250	0.762	389.228	0.039	−9.986E+03	0.050			1.859	0.146	2.619	0.102	0.019	
(3-3) SCP2/pers -EPS/pers	0.732	7.123E-05	30.851	0.006	−524.6376	0.049			0.601	0.288	5.037	0.018	0.029	
(3-4) SCP2-SST	71.113	0.499	7.081E-05	1.272E-10	−2.322E-13	6.135E-10			544.025	0.719	44.517	5.699E-10	1.524E+08	
(4-1) SCP3-SAL	−14,584.345	0.026	0.026	1.073E-05	−2.013E-09	2.335E-05			15,465.411	0.598	17.342	4.283E-05	6.547E+06	
(4-2) SCP3/pers -INC/pers	0.735	2.436E-04	0.079	0.016	−0.0073	0.045			0.621	0.238	4.120	0.034	5.437	
(4-4) SCP3-SST	5,723.021	0.088	0.001	5.853E-07	−4.732E-12	9.089E-07			13,509.089	0.693	25.834	2.864E-06	1.475E+08	
(6-4) ELC-SST	97,363.150	0.713	0.256	1.890E-06	−8.598E-10	1.620E-06			1.102E+06	0.549	18.685	8.056E-06	1.487E+08	

(Contd...)

Table A4: ***(Continued)***

Variables	Constant	(p)	x	(p)	x^2	(p)	x^3	(p)	Standard errors	Adj.-R_2	F	(p)	1st turning points	2nd turning points
(6-6) ELC-RES	456,004.346	0.175	20.368	0.014	−2.221E-05	0.032			1.455E+06	0.215	4.974	0.014	458,591.566	
(7-1) AQU-SAL	−4.517E+06	0.136	9.478	2.516E-04	−7.682E-07	0.001			1.180E+07	0.292	8.427	0.001	6.169E+06	
(7-4) AQU-SST	649,074.349	0.768	0.668	2.713E-04	−2.246E-09	4.485E-04			1.183E+07	0.288	8.287	0.001	1.487E+08	
(7-5) AQU-PEQ	−6.551E+06	0.094	10.304	0.003	−1.025E-06	0.013			1.242E+07	0.215	5.937	0.006	5.026E+06	
(5-5) SCP3-PEQ	15,011.308	0.126	−0.022	0.093	1.187E-08	0.006	−1.016E-15	2.384E-03	16,505.275	0.542	9.670	4.334E-04	907,179.824	7.785E+06
(6-2) ELC-INC	423,784.660	0.012	−1.992	0.005	8.490E-06	8.513E-10	−2.233E-12	2.185E-10	767,656.300	0.782	35.585	2.361E-09	117,333.124	2.535E+06
2021														
(1-1) CO_2-SAL	28.305	0.997	0.020	0.002	−1.588E-09	0.002			21,653.310	0.308	6.348	0.007	6.193E+06	
(1-4) CO_2/pers-SST/pers	−0.331	0.653	0.012	0.010	−8.803E-06	0.010			1.619	0.202	4.037	0.032	659.117	
(1-7) CO_2/pers-TSR/pers	−0.193	0.792	351.596	0.026	−9,946.117	0.049			1.672	0.149	3.094	0.065	0.018	
(2-2) SCP1/pers-INC/pers	−0.438	0.304	0.007	0.015	−4.875E-06	0.022			1.162	0.124	3.330	0.049	685.146	
(3-1) SCP2-SAL	−241.925	0.374	0.001	0.002	−4.047E-11	0.022			929.480	0.314	8.548	0.001	7.887E+06	
(3-4) SCP2-SST	−7.852	0.973	1.232E-04	0.001	−3.989E-13	0.001			965.028	0.260	6.809	0.004	1.545E+08	
(4-4) SCP1+2/pers-SST/pers	−0.436	0.304	0.007	0.013	−4.955E-06	0.019			1.154	0.131	3.478	0.043	684.449	
(5-1) SCP3-SAL	−7,813.687	0.255	0.018	0.001	−1.416E-09	0.001			17,987.563	0.369	8.011	0.002	6.445E+06	
(5-7) SCP3/pers-TSR/pers	−0.114	0.709	190.060	0.005	−5712.342	0.009			0.700	0.240	4.799	0.019	0.017	
(6-4) ELC-SST	136,813.554	0.685	0.219	1.070E-04	−7.227E-10	9.282E-05			1.301E+06	0.436	11.041	3.983E-04	1.516E+08	
(7-1) AQU-SAL	−3.906E+06	0.274	8.955	0.002	−7.397E-07	0.003			1.300E+07	0.217	5.850	0.007	6.053E+06	
(7-4) AQU/pers-SST/pers	−302.719	0.102	4.026	0.001	−2.933E-03	0.003			532.498	0.226	6.106	0.006	686.383	
(7-5) AQU-PEQ	−6.551E+06	0.125	10.517	0.004	−9.940E-07	0.018			1.308E+07	0.207	5.575	0.008	5.291E+06	
(8-4) WST/pers-SST/pers	−33.543	0.100	0.371	0.007	−2.593E-04	0.010			46.880	0.186	4.312	0.024	716.103	
(6-6) ELC-RES	1.002E+06	0.005	−52.538	0.013	7.260E-04	0.003	−1.731E-09	5.085E-03	1.260E+06	0.471	8.727	4.769E-04	36,184.397	2.796E+05
(8-4) WST/pers-SST/pers	75.292	0.011	−1.207	0.002	4.700E-03	1.478E-04	−2.920E-06	7.533E-05	35.147	0.542	12.460	3.068E-05	128.347	1.073E+03

Sources: Author's calculation based on the environmental reports/ESG data of each company. The data is presented to three digits after the decimal point to ensure rigor. If zero continues after the third digit (e.g., −0.0000063613), it is not presented as 0.000, but as an exponent, −6.361E-06. The amount exceeding one million yen, i.e., seven digits, is also indicated as an exponent

Table A5: Significant combination of dependent and explanatory valuables of cubic increase (positive: $\beta > 0$)

Variables	Constant	(p)	x	(p)	x^2	(p)	x^3	(p)	St. errors	Adj.-R_2	F	(p)	1st turning points	2nd turning points
2019														
(3-4) SCP2/pers-RES/pers	−0.050	0.321	0.991	1.176E-05	−0.856	2.751E-08	0.1706	1.324E-10	0.174	0.914	103.104	1.476E-14	0.579	3.347
(6-4) ELC/pers-SST/pers	−9.239	0.580	0.595	0.017	−0.002	0.029	0.0000	0.0413	20.930	0.216	3.301	3.925E-02	186.326	1,135.218
(8-4) WST-SST	−138,042.491	0.348	0.255	0.006	−2.313E-08	0.007	7.773E-17	0.0072	401,059.091	0.167	3.067	4.413E-02	5.516E+06	1.984E+08
2020														
(1-1) CO_2/pers-SAL/pers	−2.014	0.094	0.161	0.030	−0.003	0.014	1.922E-05	0.003	0.809	0.831	33.826	2.181E-07	26.178	106.887
(1-4) CO_2/pers-PEQ/pers	−1.067	0.195	0.091	0.037	−0.002	0.015	8.592E-06	0.002	0.775	0.845	37.406	1.050E-07	29.834	117.886
(2-4) SCP1/pers-SST/pers	−0.674	0.164	0.009	0.010	−1.003E-05	0.018	2.232E-09	0.026	1.197	0.126	2.631	0.068	472.833	2,995.360
(3-1) SCP2/pers-SAL/pers	−0.006	0.437	0.002	0.002	−3.273E-05	1.587E-05	1.817E-07	9.921E-08	501.698	0.761	37.106	2.232E-10	23.730	120.066
(4-1) SCP1+2-SAL	−3,328.866	0.445	0.015	0.016	−3.694E-09	0.024	2.074E-16	0.033	10,863.603	0.106	2.270	1.014E-01	2.054E+06	1.187E+07
(4-4) SCP1+2/pers-SST/pers	−0.695	0.154	9.109E-03	0.013	−9.540E-06	0.025	2.120E-09	0.035	1.198	0.115	2.390	0.089	477.370	2,999.672
(8-4) WST/pers-SST/pers	−41.721	0.036	0.488	0.002	−4.956E-04	0.005	1.086E-07	0.008	44.391	0.201	3.845	0.019	492.589	3,041.801
2021														
(1-1) CO_2/pers-SAL/pers	−3.353	0.040	0.201	0.019	−0.003	0.020	1.273E-05	0.011	1.042	0.669	17.188	7.198E-06	35.726	147.412
(1-4) CO_2-SST	3,879.688	0.696	0.007	0.028	0.000	0.045	9.280E-19	0.047	24,298.176	0.129	2.185	0.120	1.146E+07	2.191E+08
(2-4) SCP1/pers-SST/pers	−3.332	0.008	0.198	0.003	−0.003	0.002	1.302E-05	9.564E-04	0.904	0.470	10.759	5.788E-05	33.701	150.692
(2-5) SCP1/pers-PEQ/pers	4,284.911	0.057	−38.135	0.040	0.087	0.020	3.836E-04	0.006	10,085.559	0.177	3.363	0.032	218.525	−151.658
(4-1) SCP1+2/pers-SAL/pers	−3.288	0.008	0.197	0.003	−2.921E-03	0.002	1.296E-05	8.497E-04	0.889	0.485	11.350	3.840E-05	33.655	150.297
(4-3) SCP1+2-EPS	4,783.412	0.029	−38.449	0.033	0.090	0.014	3.872E-04	0.005	9,748.231	0.198	3.713	0.022	213.784	−154.847
(7-4) AQU-SST	−3.384E+06	0.402	3.381	0.013	−1.519E-07	0.031	4.633E-16	0.034	1.382E+07	0.115	2.518	0.076	1.113E+07	2.185E+08
(8-1) WST/pers-SAL/pers	−130.729	0.010	8.092	0.003	−0.125	0.002	5.630E-04	0.001	34.989	0.547	12.651	2.736E-05	32.441	147.689

Sources: Author's calculation based on the environmental reports/ESG data of each company. The above cases are those in which the third term is positive in the cubic equation. The notation of decimal points and numbers exceeding one million are the same as those in Table A4. TSR has no cases while SST has eight cases, indicating a cubic increase in environmental impacts, with two cases in 2019, three in 2020, and three in 2021