SSRG International Journal of Economics and Management Studies
ISSN: 2393–9125 / https://doi.org/10.14445/23939125/IJEMS-V12I6P101

Volume 12 Issue 6, 1-22, June 2025

Original Article

Growth and Environmental Conservation in Japan's Major Railway Corporations

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Received: 07 April 2025 Revised: 19 May 2025 Accepted: 02 June 2025 Published: 16 June 2025

Abstract *- This study examines growth and environmental conservation in Japan's major railway corporations. The analysis utilizes financial, transport, and environmental performance data from 20 publicly traded entities from 2019 to 2023. Each fiscal year is analyzed separately, covering the periods before, during, and after the COVID-19 pandemic. The study is structured around three points. First, the regression analyses based on the Environmental Kuznets Curve (EKC) hypothesis identify turning points from JPY 0.068 to 0.117 in Passengers Per Employee (PAX/EMP). These turning points establish target thresholds for railway companies for Scope 1 CO_2 Emissions per employee (SCP1/EMP) and combined Scope 1 and 2 CO_2 emissions per employee (SCP1+2/EMP) relative to PAX/EMP. Second, the validation of the EKC hypothesis results from the combined influence of four key factors:(1) railway companies have adopted decarbonization technologies and pursued energy efficiency in their operations;(2) the growing emphasis on ESG principles by institutional investors has created additional incentives for environmental performance;(3) the influence of external guidance and evaluations has driven corporate engagement in environmental conservation; and (4) regulatory authorities have tightened emissions controls in line with domestic and international climate commitments. Third, and most importantly, increasing PAX/EMP to the threshold range validates the EKC hypothesis and enables corporate growth while achieving environmental conservation in Japan's major railway corporations.*

Keywords *- EKC hypothesis, ESG, Decarbonization, Passengers per employee, Scope 1 and 2.*

1. Introduction

Using data on financial, transport, and environmental performance from 20 publicly listed firms from 2019 to 2023, in this study, the author examines how major railway corporations in Japan achieve corporate growth and environmental conservation. Each fiscal year (FY) is analyzed separately, covering the periods before, during, and after the COVID-19 pandemic.

The author focuses on railway companies' financial and transport growth and environmental conservation. The results contribute to advancing academic research, corporate strategic planning, and policymaking.

This section presents the advantages of focusing on listed railway companies in Japan and highlights unexplored research frontiers to provide context for this study's primary objective. Japanese railway corporations face new management challenges; addressing these developments necessitates new perspectives and methodologies for analysis. The key challenges include declining transport performance because of an ageing population, low birth rate, rural depopulation, difficulty recruiting AI-skilled personnel, and the growing need to engage In Environmental, Social, and Governance (ESG) focused investments. The Japanese government has pledged to achieve a 46% reduction in carbon dioxide (CO_2) emissions by 2030 (2013 baseline) and plans to set a 60% reduction target for 2035. Furthermore, mandatory disclosure of environmental data in annual securities reports by listed companies is set to come into effect by 2027. These factors require comprehensive management and environmental strategies for railway companies.

Despite these challenges, there are promising opportunities, such as autonomous driving technology and Variable Voltage Variable Frequency (VVVF) inverters, also called Variable-Frequency Drive (VFD), which improves energy efficiency and motor control. Experimental trials of the hydrogen-hybrid advanced rail vehicle for innovation (HYBARI) are in progress, representing a potential step toward decarbonization in the railway industry. Another new development is the planned launch of the magnetic levitation (maglev) train system, which is expected to generate significant economic benefits because of its high speed (500 km/h).

Additionally, several promising socio-economic trends may help the industry grow, such as the gradual return to office-based work after the COVID-19 pandemic, increased tourism, and diversification of revenue sources, particularly expanding premium-class railway services that cost more. These challenges and opportunities highlight the potential for expanding research frontiers in the railway industry.

This study examines 20 railway corporations listed on the Tokyo Stock Exchange (TSE) that have disclosed financial, transport, and environmental data. Their combined sales volume was JPY 14.886 trillion (approximately USD 104 billion) in 2023 (see Section 2.3). This study's findings and implications provide valuable insights for research on countries, cities, and corporate clusters with similar characteristics.

Recent economic developments suggest that research on corporate competition and environmental conservation will continue to expand. Two recipients of the Nobel Prize in Economic Sciences have notably advanced the academic frontiers of this field. Dr. Jean Tirole, awarded in 2014, contributed to the theoretical understanding of market power and regulatory economics, while Dr. William D. Nordhaus, awarded in 2018, integrated climate change into long-term macroeconomic analysis. These contributions underscore the potential for further academic inquiry at the intersection of corporate behavior, environmental disclosure, and policy design.

This study adopts the Environmental Kuznets Curve (EKC), focusing on publicly listed railway companies. Unlike conventional approaches that primarily analyze countries or regions, this study applies the EKC and its extended theory of an inverted N-shaped curve at the firm level.

Through the author's review of the literature, it becomes evident that there is a gap in integrating EKC analysis with financial and transport performance in Japan. Many studies focus on cost efficiency in railways; however, no existing research has integrated EKC analysis with financial performance, transport performance, and environmental impact in Japanese railway companies.

A preliminary investigation of the author shows a positive correlation between the number of employees, passengers, and CO_2 emissions, highlighting the need to identify the key indicators of corporate growth and environmental conservation. This finding serves as the foundation for this study's analytical framework.

Financial, transport, and environmental data from 20 railway corporations in Japan are analyzed to identify targets for growth and conservation. Specifically, regression analyses based on the EKC identify turning points ranging from JPY 0.068 to 0.117 in Passengers Per Employee (*PAX/EMP*). These turning points are the benchmarks for Scope 1 CO_2 Emissions Per Employee (*SCP1/EMP*) and combined Scope 1 and 2 CO_2 emissions per employee (*SCP1 + 2/EMP*) relative to *PAX/EMP*.

This study provides insights for academic research, corporate strategic planning, and policymaking, contributing to a deeper understanding of growth and conservation. Enhancing the combination of (*SCP1/EMP – PAX/EMP*) and (*SCP1+2/EMP – PAX/EMP*) to the identified threshold range is the key benchmark for empirically demonstrating the EKC hypothesis and achieving these objectives.

Furthermore, this study's ESG-based and *PAX/EMP*-based approach advances the research frontier in environmental economics and industrial organization.

This study is grounded in the author's prior research efforts and analytical approaches. However, those earlier works are not directly cited in this manuscript in accordance with the journal's editorial policy.

2. Definitions and Limitations of Prior Studies and Challenges

2.1. Definitions

"Financial growth" is increased sales, net income, and other significant financial indicators.

"Transport growth" refers to an increase in the number of employees, passengers, and passenger kilometres rather than an expansion in a physical network.

"Environmental conservation" is defined by Article 2 of the Basic Environment Act (Act No. 91 of 1995) in Japan. As legally stipulated, it includes 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.

This study adopts the Environmental Kuznets Curve (EKC) hypothesis as the framework, which suggests a non-linear relationship between economic growth and environmental degradation. At early stages of growth, environmental burdens tend to intensify, but once a certain income level is reached, these pressures begin to ease, forming an inverted U-shape.

This theoretical framework is derived from Dr. Simon Kuznets's classical study of income inequality and economic growth, for which he received the Nobel Prize in Economics. Since its emergence in the early 1990s through foundational works by Grossman and Krueger (1991) and the World Bank

(1992), the EKC hypothesis has inspired a broad range of studies addressing diverse environmental challenges, including air and water pollution and deforestation, as examined by Csereklyei et al. (2017), Galeotti et al. (2009), Gopakumar (2022), Markandya et al. (2006), Panayotou (1997), Perman et al. (1999), Selden et al. (1999), Sorgea et al. (2020), and Stern et al. (2001). [1]-[11]

The EKC expresses the hypothesis that economic growth and environmental degradation have an inverse relationship, which is characterized by an inverted U-shaped curve. There is increasing environmental degradation in the initial stages of economic growth; however, beyond a specific threshold, the environmental impact starts declining. When the linear term ($\beta > 0$) and the squared term ($\beta < 0$) are both statistically significant, the validity of the hypothesis is confirmed (see Fig. 2 in Section 3.2 for details).

Fig.1 presents the relationship between Scope 1 and 2 CO_2 emissions per employee and the number of passengers per employee (*SCP1+2/EMP – PAX/EMP*) in 2019. It also shows Scope 1 CO_2 emissions per employee and the number of passengers per employee (*SCP1/EMP – PAX/EMP*) 2021 within the EKC framework.

This study extends the EKC hypothesis by examining the applicability of a cubic model. This approach considers an inverted N-shaped curve, which reflects a more complex relationship between growth and environmental impact.

Specifically, environmental impact increase ($\beta > 0$) at the first turning point (bottom) and then decline ($\beta < 0$) at the second turning point (top). The empirical analysis demonstrates the validity of this approach.

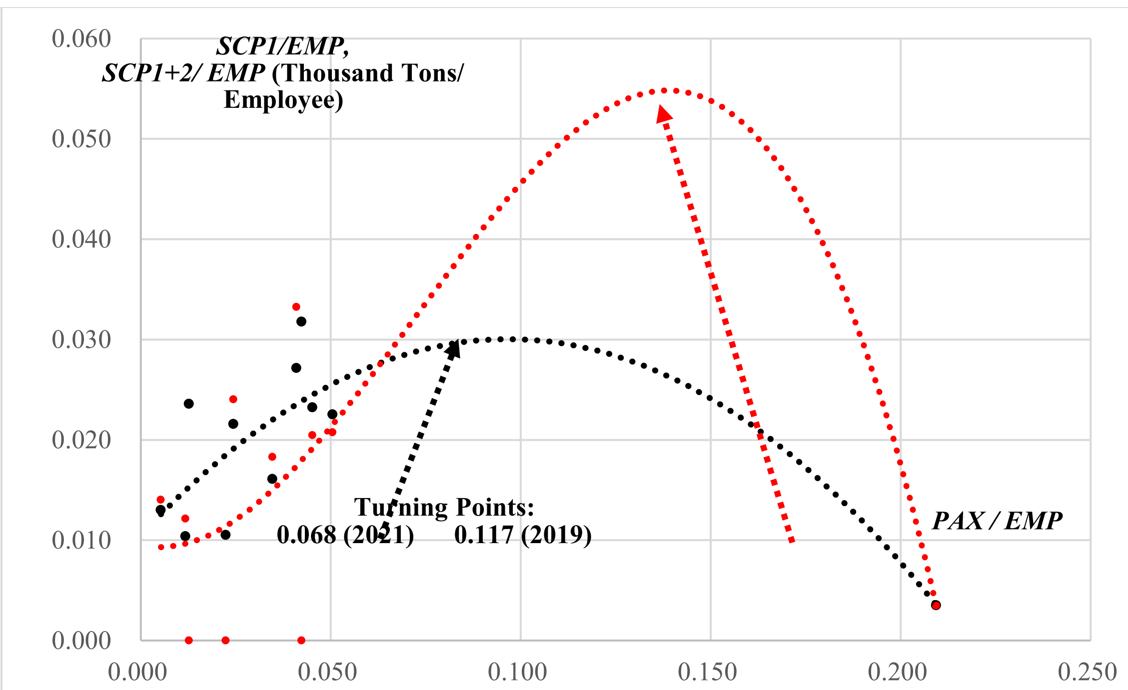


Fig. 1 ***SCP1+2/EMP – PAX/EMP*** **in 2019 and** ***SCP1/EMP – PAX/EMP*** **in 2021**

This study investigates the interaction between corporate financial and transport performance and environmental impact, particularly CO_2 emissions, to identify a turning point or a range of turning points simultaneously achieving corporate growth and environmental conservation. Table 4 in Section 3 provides a detailed list of the analysed companies.

2.2. Limitations of Prior Studies

No study has used a complete dataset of listed Japanese railway companies within the EKC hypothesis framework to examine the relationship between corporate financial and transport growth and environmental conservation.

A significant limitation in research on corporate ESG arises from the over-reliance on secondary ESG scores, such as ratings (A, AA, or numerical scores) assigned by agencies and organizations. These scores often lack transparency and cannot provide an objective assessment. Few studies use primary raw data as inconsistent disclosure requirements and limited environmental information hinder comprehensive analyses.

Environmental data disclosure requires significant time and resource allocation, including certification by auditing firms, and may involve disclosing sensitive corporate information. Furthermore, weak coordination among regulatory authorities, industry associations, legal and accounting firms, financial institutions, and media organizations has resulted in inconsistencies in disclosure practices across firms, which leads to information asymmetry. Although corporations must disclose financial data during the listing process for legal and financial reviews, environmental data, essential for academic research, remain unavailable with the same level of promptness or reliability.

The Corporate Governance Code, issued by the Tokyo Stock Exchange (TSE) in 2021, highlights this issue. [12] The Code outlines key principles for effective corporate governance.

The Code (TSE, 2021) states, "Information disclosure by listed companies in Japan is highly comparable regarding financial statements, as the formats, preparation guidelines, and other requirements are well defined. However, non-financial information, including explanations related to financial conditions, business strategies, risks, governance, and social and environmental issues (commonly referred to as ESG factors), is often criticized for its templated and vague descriptions, which lack specificity and added value."

Indeed, some companies only provide bar graphs or approximated values related to environmental data and fail to present the exact figures required for rigorous academic analysis. The recently implemented Greenhouse Gas Emissions Reporting and Publication Scheme by the Ministry of the Environment of Japan requires companies to estimate CO_2 emissions for individual sites. However, the scheme does not integrate company-wide emissions; it excludes data from offices and facilities outside its scope.

Additionally, TSE-listed companies must comply with sustainability-related information disclosure requirements by 2027. However, as of April 2025, how these regulations affect academic research remains uncertain.

Another challenge in utilizing raw ESG data stems from inconsistent disclosure practices and the substantial effort required for data collection and processing. Unlike financial disclosures, which are often provided in a structured format, such as Excel or CSV, ESG data are rarely available in an accessible format. This study manually extracted data from ESG reports (50 to 100 pages long) and corporate websites, followed by extensive data entry and verification.

To overcome these challenges, this study bases its calculations on primary data disclosed by firms, ensuring minimal biases and avoiding the arbitrariness inherent in secondary data. This methodological approach is significantly different from previous studies; although it is labor-intensive, it contributes substantially to the knowledge in this field.

2.3. Impacts and Challenges

This section examines the economic and environmental impacts of the 20 railway corporations analyzed in this study to provide a comprehensive perspective. According to the annual securities reports, the combined sales volume of all 20 companies is estimated to be JPY 14.886 trillion (approximately USD 104 billion) in 2023. This figure is equivalent to the gross domestic product (GDP) of some countries, such as Bulgaria or Uzbekistan (USD 101 billion in 2023) (International Monetary Fund, 2024).[13] Moreover, it is comparable to the GDP of a single state in the US, such as West Virginia (USD 102 billion) or New Hampshire (USD 114 billion) (US Bureau of Economic Analysis, 2025).[14]

The total number of railway passengers in Japan declined from 23.685 billion in 2013 to 22.614 billion in 2023, a reduction of 4.5%. Similarly, the number of passengers per – kilometer decreased from 414.421 billion in 2013 to 393.706 billion in 2023, a reduction of 5.0% (Ministry of Transport, 2024).[15]

The latest data from the Ministry of the Environment of Japan (2024) indicate that Japan's Greenhouse Gas (GHG) emissions in 2022 amounted to approximately 1.085 billion tons (CO_2 equivalent), which is a 2.3% decrease (approximately 25.1 million tons) compared with 2021 and a 22.9% reduction compared with the baseline year of 2013.[16] The combined Scope 1 and 2 CO_2 emissions of the 20 railway corporations are estimated to be 10.02 million metric tons in 2022, which is comparable to Mozambique's (10.02 million metric tons) or the Kyrgyz Republic's (10.31 million metric tons) CO_2 emissions in the same year (European Commission, 2024).[17]

These 20 companies employ 411,388 workers, approximately equivalent to the combined workforce of Microsoft and Alphabet Inc. as of the end of 2023.[18] Microsoft employs approximately 221,000 people (Microsoft, 2023), while Alphabet Inc. (Google) employs around 182,000 people (Alphabet, 2023).[19] Given the scale and influence of these companies, the firms analyzed in this study warrant academic attention.

3. Verification

3.1. Methods

The 20 TSE-listed firms analyzed in this study are categorized as follows:

- Four are publicly listed passenger railway companies, among six passenger and one freight railway company, which were privatized and separated from Japanese National Railways in 1987.
- Sixteen publicly listed companies are classified as "major private railways" by the Japan Private Railway Association (2025).[20] These were selected from approximately 270 private railway companies in Japan (Table 4 presents a list of company names).

Because of the merger of Hankyu Hanshin Holdings, the number of railway groups in the final analysis should be 19. However, as Hankyu Hanshin Holdings continues to operate its railway companies as separate entities even after the merger, the total number of railway corporations analyzed in this study remains at 20.

Despite variations in financial and transport performance, these 20 companies are vital to economic and social development along their railway networks. They also contribute to Japan's overall progress by facilitating mobility, providing employment and business opportunities, generating shareholder value and tax revenues, and enhancing quality of life.

Compared with other transportation modes, such as automobiles and air travel, railways offer mass transportation solutions, alleviate urban congestion, and have a lower environmental impact.

3.1.1. Data Coverage and Methodology

This study's cross-sectional analysis is conducted on data from FY2019 to FY2023, with each fiscal year analyzed separately. Regression analysis requires at least three to four years of data to ensure statistical validity; however, environmental impact data prior to FY2018 are often incomplete or inconsistent, rendering them unsuitable for analysis.

This study did not conduct time-series analysis because of the risk of spurious regression results. Moreover, this study uses an inductive approach to evaluate corporate performance based on established financial, transport, and environmental performance indicators and a systematic review of disclosed information.

Despite these limitations, this study provides insights into the conditions before, during, and after the COVID-19 pandemic. The findings have implications for corporate growth and environmental conservation.

3.1.2. Variables

Table 1 presents the dependent and explanatory variables used in this study. To enhance analytical accuracy and ensure the comparability of results, all of the variables are standardized through normalization based on the number of Employees (*EMP*), number of Passengers (*PAX*), and Passenger–kilometers (*PKM*).

3.1.3. Regression Model Specifications

A total of 1,215 regression equations are estimated in this study, which are categorized into two types:

- 360 equations in the basic regression model and
- 855 equations in the advanced regression model. Table 1 presents the details.

Definitions of Scope 1 and 2 emissions (US Environmental Protection Agency, 2021).[21]

- Scope 1 emissions are direct GHG emissions from sources controlled or owned by an organization (e.g., emissions associated with fuel combustion in boilers, furnaces, and vehicles).
- Scope 2 emissions are indirect GHG emissions associated with purchasing electricity, steam, heat, or cooling.
- Scope 3 emissions are not considered in this study, as some companies do not disclose that data.

3.1.4. Data Sources and Collection Process

Financial Data

Annual securities reports (Yuka Shouken Hokokusho, abbreviated to Yuho in Japanese) filed by corporations in Japan are equivalent to Form 10-K in the US. Statutory audit reports submitted to the Finance Bureau of the Ministry of Finance ensure the reliability of the Yuho.

Explanatory variables (1 – 4) are systematically listed in a standardized format at the beginning of the Yuho, serving as the foundation for the financial analysis.

Transport Data

Transport data are manually collected from corporate sustainability reports and integrated reports.

Environmental Impact Data

Similarly, environmental impact data are manually collected from each corporate environmental report and ESG report.

The financial, transport, and environmental data of the companies analyzed in this study are as follows (words such as "Holdings" and "Corporation" are omitted here for simplicity): Central Japan Railway (2024ab), East Japan Railway (2024ab), Hankyu Hanshin (2024ab), Keihan (2024ab), Keikyu (2024ab), Keio (2024ab), Keisei Electric Railway (2024ab), Kintetsu (2024ab), Kyushu Railway (2024ab), Nagoya Railroad (2024ab), Nishi-Nippon Railroad (2024ab), Nankai Electric Railway (2024ab), Seibu (2024ab), Odakyu Electric Railway (2024ab), Soutetsu (2024ab), Tobu Railway (2024ab), Tokyo Metro (2024ab), Tokyu (2024ab), and West Japan Railway (2024ab).[22]-[59]

Hankyu Hanshin Holdings was formed by the merger of two independent railway groups. Following the merger, the holding company oversees two separate railway corporations, Hankyu Corporation and Hanshin Electric Railway, which are legally distinct entities under the consolidated structure.

This study adopts a consolidated data analysis approach, as non-consolidated environmental data are not fully disclosed.

Table 1. Dependent and Explanatory Variables (Abbreviations)

1. Basic Regression Model: 360 Cases	
Dependent Variables: 3	Explanatory Variables: 8
(1) Scope 1 CO_2 Emissions (*SCP1*) (2) Scope 2 CO_2 Emissions (*SCP2*) (3) Scope 1+2 CO_2 Emissions (*SCP1+2*) Unit: Thousand tons CO_2 Dependent Variables × Explanatory Variables: 3×8=24 Cases Three Models (Linear, Quadratic, and Cubic): 24×3=72 Cases Five-Year Analysis: 72×5=360 Cases	(1) Net Sales (*SAL*) (2) Net Income (*INC*) (3) Total Assets (*SST*) (4) Earnings per Share (*EPS*) (5) Total shareholders Return (*TSR*) (6) Number of Staff (*EMP*) (7) Number of Passengers (*PAX*) (8) Passenger-Kilometers (*PKM*) Unit: (1, 2, 3, 5): Million JPY, (4): JPY (7) Persons, (8) Million Persons, (9) Million Kilometers
2. Advanced Regression Model Normalized by *EMP, PAX*, and *PKM*: 855 Cases	
(1) Normalized by *EMP*: 315 cases	
Dependent Variables: 3	Explanatory Variables: 7
(1-E) Scope 1 CO_2 emissions per Employee: *SCP1/EMP* (2-E) *SCP2/EMP* (3-E) *SCP1+2/EMP* Dependent Variables × Explanatory Variables: 3×7=21 Cases Three Models (Linear, Quadratic, and Cubic): 21×3=63 Cases Five-Year Analysis: 63×5=315 Cases	(1-e) Net sales per Employee: *SAL/EMP* (2-e) *INC/EMP* (3-e) *SST/EMP* (4-e) *EPS/EMP* (5-e) *TSR/EMP* (6-e) *PAX/EMP* (7-e) *PKM/EMP*
(2) Normalized by *PAX*: 270 Cases	
Dependent Variables: 3	Explanatory Variables: 6
(1-P) Scope 1 CO_2 emissions per passenger: *SCP1 / PAX* (2-P) *SCP2 / PAX* (3-P) *SCP1 + 2/PAX* Dependent Variables × Explanatory Variables: 3×6=18 Cases Three Models (Linear, Quadratic, and Cubic): 18×3=54 Cases Five-Year Analysis: 54×5=270 cases	(1-p) Net sales per passenger: *SAL/PAX* (2-p) *INC/PAX* (3-p) *SST/PAX* (4-p) *EPS/PAX* (5-p) *TSR/PAX* (6-p) *EMP/PAX*
(3) Normalized by *PKM* 270: Cases	
Dependent variables: 3	Explanatory Variables: 6
(1-K) Scope 1 CO_2 Emissions per passenger-Kilometer: *SCP1/PKM* (2-K) *SCP2/PKM* (3-K) *SCP1+2/PKM* Dependent Variables × Explanatory Variables: 3×6=18 Cases Three Models (Linear, Quadratic, and Cubic): 18×3=54 Cases Five-Year Analysis: 54×5=270 Cases	(1-k) Net sales per Passenger-Kilometer: *SAL/PKM* (2-k) *INC/PKM* (3-k) *SST/PKM* (4-k) *EPS/PKM* (5-k) *TSR/PKM* (6-k) *EMP/PKM*

- The significance level of the p-value is set at 5% ($p < 0.05$). Nonsignificant results are omitted from the text for the sake of conciseness. Data are reported up to three decimal places to ensure precision. If the first three decimal places are zeros (e.g., 0.0003585504), values beyond the third decimal place are expressed in exponential notation rather than rounded to 0.000 (i.e., 3.586E-04).

In the linear regression model, *SCP1* is the dependent variable, while *SAL*, *INC*, *SST*, *EPS*, *TSR*, *EMP*, *PAX*, and

PKM are the explanatory variables. Next, the analysis is extended by setting *SCP2* as the dependent variable, followed by a comprehensive model where *SCP1*+2 is set as the dependent variable.

The combinations of dependent and explanatory variables are systematically computed. Only select combinations are presented in this paper to maintain clarity and prevent unnecessary complexity.

Regression equations: Linear model specification
The regression models are formulated as follows.

$$
\begin{gathered}
Y\,(SCP1) = \alpha + \beta\,(SAL) + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(INC) + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(SST) + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(EPS) + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(TSR) + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(EMP) + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(PAX) + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(PKM) + \varepsilon \\
\vdots \\
Y\,(SCP2) = \alpha + \beta\,(SAL) + \varepsilon \\
\vdots \\
Y\,(SCP1+2) = \alpha + \beta\,(SAL) + \varepsilon \\
\vdots
\end{gathered}
$$

The "⋮" symbol indicates omissions.

Y represents the dependent variable, α denotes the intercept, β signifies the coefficient of the explanatory variable, and ε indicates the error term. The significance of the intercept is not considered.

The formulas of Scope 1 CO_2 emissions, Scope 2 CO_2 emissions, and the combined Scope 1 and 2 CO_2 emissions are expressed in different unit formats: per employee (*SCP1/EMP*, *SCP2/EMP*, and *SCP1+2/EMP*), per passenger (*SCP1/PAX*, *SCP2/PAX*, and *SCP1+2/PAX*), and per passenger–kilometer (*SCP1/PKM*, *SCP2/ PKM*, and *SCP1+2/PKM*).

$$
\begin{gathered}
Y\,(SCP1/EMP) = \alpha + \beta\,(SAL/EMP) + \varepsilon \\
\vdots \\
Y\,(SCP1/PAX) = \alpha + \beta\,(SAL/PAX) + \varepsilon \\
\vdots \\
Y\,(SCP1/PKM) = \alpha + \beta\,(SAL/PKM) + \varepsilon \\
\vdots \\
Y\,(SCP2/EMP) = \alpha + \beta\,(SAL/EMP) + \varepsilon \\
\vdots \\
Y\,(SCP1+2/EMP) = \alpha + \beta\,(SAL/EMP) + \varepsilon \\
\vdots \\
(omitted\ for\ brevity)
\end{gathered}
$$

The second objective is to evaluate the EKC hypothesis. Scope 1, Scope 2, and the combined Scope 1 and 2 CO_2 emissions are formulated as follows:

$$
\begin{gathered}
Y\,(SCP1) = \alpha + \beta\,(SAL) + \beta\,(SAL)^2 + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(INC) + \beta\,(INC)^2 + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(SST) + \beta\,(SST)^2 + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(EPS) + \beta\,(EPS)^2 + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(TSR) + \beta\,(TSR)^2 + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(EMP) + \beta\,(EMP)^2 + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(PAX) + \beta\,(PAX)^2 + \varepsilon \\
Y\,(SCP1) = \alpha + \beta\,(PKM) + \beta\,(PKM)^2 + \varepsilon \\
\vdots \\
Y\,(SCP2) = \alpha + \beta\,(SAL) + \beta\,(SAL)^2 + \varepsilon \\
\vdots \\
Y\,(SCP1+2) = \alpha + \beta\,(SAL) + \beta\,(SAL)^2 + \varepsilon \\
\vdots \\
(omitted\ for\ brevity)
\end{gathered}
$$

Building on the previous analysis, the validity of the EKC hypothesis is examined on a per-unit basis. The formulas for Scope 1, Scope 2, and the combined Scope 1 and 2 CO_2 emissions are expressed per employee (*SCP1/EMP*, *SCP2/EMP*, and *SCP1+2/EMP*), per passenger (*SCP1/PAX*, *SCP2/PAX*, and *SCP1+2/PAX*), and per passenger–kilometer (*SCP1/PKM*, *SCP2/PKM*, and *SCP1+2/PKM*).

$$
\begin{gathered}
Y\,(SCP1/EMP) = \alpha + \beta\,(SAL/EMP) + \\
\beta\,(SAL/EMP)^2 + \varepsilon \\
\vdots \\
Y\,(SCP2/EMP) = \alpha + \beta\,(SAL/EMP) + \\
\beta\,(SAL/EMP)^2 + \varepsilon \\
\vdots \\
Y\,(SCP1+2/EMP) = \alpha + \beta\,(SAL/EMP) + \\
\beta\,(SAL/EMP)^2 + \varepsilon \\
\vdots \\
(omitted\ for\ brevity)
\end{gathered}
$$

The third objective is to verify the presence of an inverted N-shaped curve. Scope 1, 2, and the combined Scope 1 and 2 CO_2 emissions are formulated as follows.

$$
\begin{gathered}
Y\,(SCP1) = \alpha + \beta\,(SAL) + \beta\,(SAL)^2 + \\
\beta\,(SAL)^3 + \varepsilon \\
\vdots \\
Y\,(SCP2) = \alpha + \beta\,(SAL) + \beta\,(SAL)^2 + \\
\beta\,(SAL)^3 + \varepsilon \\
\vdots \\
Y\,(SCP1+2) = \alpha + \beta\,(SAL) + \beta\,(SAL)^2 + \\
\beta\,(SAL)^3 + \varepsilon \\
\vdots \\
(omitted\ for\ brevity)
\end{gathered}
$$

Building on the preceding analysis, different normalization units are used to verify the presence of an inverted N-shaped curve.

The formulas for Scope 1, Scope 2, and the combined Scope 1 and 2 CO_2 emissions are presented per employee (*SCP1/EMP*, *SCP2/EMP*, and *SCP1+2/EMP*), per passenger (*SCP1/PAX*, *SCP2/PAX*, and *SCP1+2/PAX*), and per passenger-kilometer (*SCP1/PKM*, *SCP2/PKM*, and *SCP1+2/PKM*).

$$Y\,(SCP1/EMP) \;=\; \alpha \;+\; \beta\,(SAL/EMP) \;+\; \beta\,(SAL/EMP)^2 \;+\; \beta\,(SAL/EMP)^3 \;+\; \varepsilon$$
$$\vdots$$
$$Y\,(SCP2/EMP) \;=\; \alpha \;+\; \beta\,(SAL/EMP) \;+\; \beta\,(SAL/EMP)^2 + \;\beta\,(SAL/EMP)^3 \;+\; \varepsilon$$
$$\vdots$$
$$Y\,(SCP1+2/EMP) \;=\; \alpha \;+\; \beta\,(SAL/EMP) \;+\; \beta\,(SAL/EMP)^2 + \;\beta\,(SAL/EMP)^3 \;+\; \varepsilon$$
$$\vdots$$
$$(omitted\ for\ brevity)$$

3.2. Results

Table 2 shows that out of the 405 cases tested in the linear regression analysis each year, 46 (11.4%) in 2019, 45 (11.1%) in 2020, 49 (12.1%) in 2021, 44 (10.9%) in 2022, and 46 (11.4%) in 2023 exhibited statistically significant monotonic relationships. These results suggest a pattern in which the environmental impact increases with financial and transport performance growth.

The results of the regression analyses provide robust empirical evidence supporting the EKC hypothesis from 2019 to 2023, which corresponds to the period before, during, and after the COVID-19 pandemic.

The quadratic regression analysis results validate the EKC hypothesis in 12 cases (3.0%) in 2019, 8 cases (2.0%) in 2020, 12 cases (3.0%) in 2021, 11 cases (2.7%) in 2022, and 9 cases (2.2%) in 2023.

Moreover, the cubic regression analyses results confirmed the presence of an inverted N-shaped curve in 4 cases (1.0%) in 2019, 5 cases (1.2%) in 2020, 4 cases (1.0%) in 2021, 7 cases (1.7%) in 2022, and 6 cases (1.5%) in 2023.

Appendix 1 details the significant results of the EKC and inverted N-shaped curve. Significant cases from the linear model are omitted because of space constraints.

Table 2. Number of Statistically Significant Cases and Percentages (%)

FYs	1 linear	2 EKC	3 inv. N-shaped
2019	46 (11.4%)	12 (3.0%)	4 (1.0%)
2020	45 (11.1%)	8 (2.0%)	5 (1.2%)
2021	49 (12.1%)	12 (3.0%)	4 (1.0%)
2022	44 (10.9%)	11 (2.7%)	7 (1.7%)
2023	46 (11.4%)	9 (2.2%)	6 (1.5%)

In 2020, the COVID-19 pandemic led Japan to declare an emergency in April, urging people to refrain from non-essential outings. All 20 railway corporations analyzed in this study experienced a year-on-year decline in revenue and recorded negative net profits. However, as the number of passengers and CO_2 emissions also declined, the number of statistically significant cases in 2020 remained essentially unchanged compared with other years.

Next, the combinations of dependent and explanatory variables that facilitate financial growth and environmental conservation are examined, identifying single or multiple turning points that should be targeted. However, exploring combinations in which the hypothesis holds over an extended period is essential. Impractical turning points cannot be considered viable targets.

Table 3 presents the cases in which the EKC hypothesis and the inverted N-shaped curve are validated and categorized by the explanatory variable.

Table 3. Number of Statistically Significant Cases Validating the EKC Hypothesis and the Inverted N-Shaped Curve

Segment	(1) Linear	(2) EKC	(3) Inv.-N	(2) +(3)
SAL	45	8	1	9
INC	28	10	5	15
SST	40	9	11	20
EPS	28	0	1	1
TSR	23	0	0	0
EMP	37	11	4	15
PAX	13	6	4	10
PKM	16	8	0	8
Total	230	52	26	78

The most frequently occurring explanatory variables in validating the EKC hypothesis and the inverted N-shaped curve are *INC*, *SST*, and *EMP*, appearing in 15, 20, and 15 cases, respectively. These cases include instances in which the variables were normalized Per Employee (/*EMP*), Passenger (/*PAX*), and Passenger–kilometer (/*PKM*).

INC, *SST*, and *EMP* exhibit the highest frequency of statistical significance in validating the EKC hypothesis and the inverted N-shaped curve. However, their turning points are too high, rendering them largely theoretical and practically unattainable (Fig. 3). These targets or benchmarks are unrealistic and impractical for many companies, whose values typically amount to only one-tenth of these levels.

Although the number of cases in which the EKC hypothesis is confirmed using *PAX* as an explanatory variable is less than that of the three aforementioned variables, the turning points identified when using passengers per employee (*PAX/EMP*) as an explanatory variable are relatively attainable. For instance, the EKC hypothesis was validated in 2019, 2020, 2021, and 2023 based on the combination of *SCP1/EMP* and *PAX/EMP*. Moreover, in 2021 and 2022, the hypothesis is confirmed by combining *SCP1+2/EMP* and *PAX/EMP*.

The turning points (ranging from 0.068 to 0.117) have already been attained or nearly attained by some companies, such as Tokyo Metro and East Japan Railway.

Furthermore, mid- and low-ranked firms in terms of sales can strategically manage their operations to reach these turning points, enabling them to achieve financial and transport growth while ensuring environmental conservation.

Fig. 2 (reproduction of Fig. 1) presents the relationship between the explanatory variable (*PAX/EMP*) on the x-axis and the dependent variables (*SCP1/EMP*) and (*SCP1+2/EMP*) on the y-axis. The figure reveals an inverted U-shaped curve, with turning points at JPY 0.068 in 2021 and JPY 0.117 in 2022.

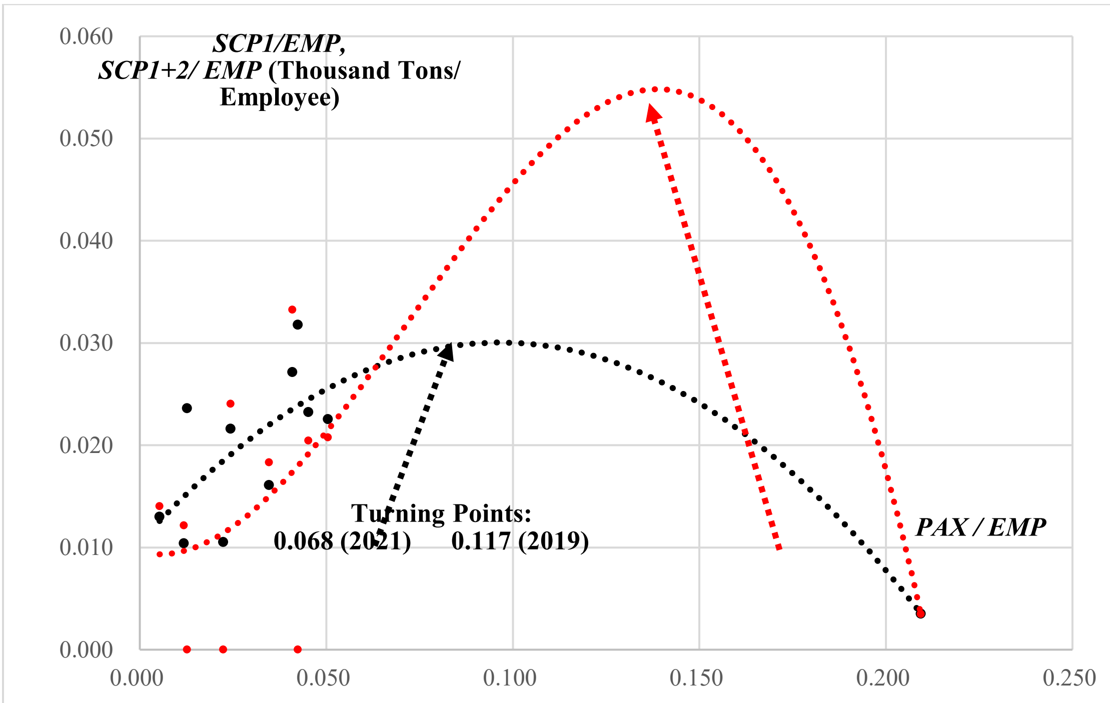


Fig. 2 ***SCP1+2/EMP – PAX/EMP*** **in 2019 and** ***SCP1/EMP – PAX/EMP*** **in 2021 (Reproduced from Fig. 1)**

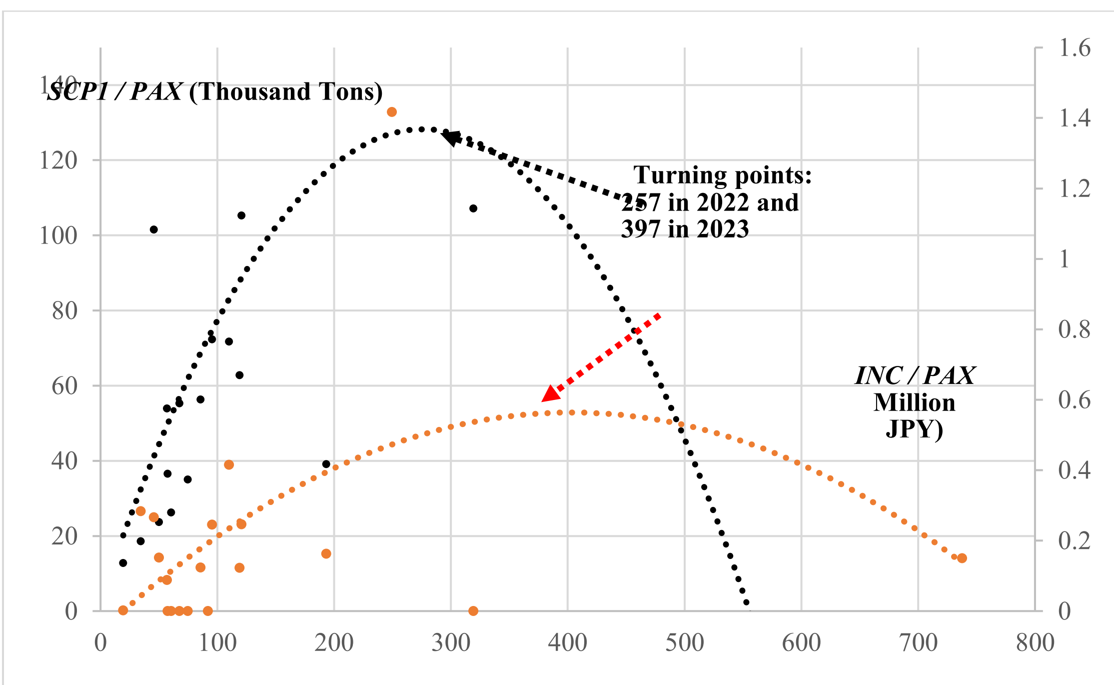


Fig. 3 ***SCP1/PAX – INC/PAX*** **in 2022 and 2023**

The two cases presented in Fig. 2 in which the EKC hypothesis was validated using *PAX/EMP* in 2019 and 2022 are as follows:

2019

$$Y\ (SCP1+2/EMP) = \alpha + \beta\ (PAX/EMP) + \beta\ (PAX/EMP)^2 + \varepsilon,$$
$$= 0.001 + 0.238\ (PAX/EMP) - 1.021\ (PAX/EMP)^2 + 0.004$$
$$(p = 0.637) \quad (0.030) \quad (0.021)$$
$$Adj.-R^2 = 0.406, F = 4.417\ (p = 0.051)*,$$
$$Turning\ point: 0.117.$$

2021

$$Y\ (SCP1/EMP) = \alpha + \beta\ (PAX/EMP) + \beta\ (PAX/EMP)^2 + \varepsilon,$$
$$= -0.016 + 0.391\ (PAX/EMP) - 2.852\ (PAX/EMP)^2 + 0.008$$
$$(p = 0.003\ ) \quad (0.058)* \quad (0.020)$$
$$Adj.-R^2 = 0.287, F = 4.627\ (p = 0.026),$$
$$Turning\ point: 0.068.$$

*The value is deemed to meet the required significance level.

Fig. 3 presents the explanatory variable (*INC/PAX*) on the x-axis and the dependent variable (*SCP1/PAX*) on the y-axis. However, this combination yields theoretical values of JPY 257 per person in 2022 and JPY 397 per person in 2023 for *INC/PAX*, which are too high and require many years to attain.

2022

$$Y\ (SCP1/PAX) = \alpha + \beta\ (INC/PAX) + \beta\ (INC/PAX)^2 + \varepsilon,$$
$$= -0.198 + 0.009\ (INC/PAX) - 1.731E-05\ (INC/PAX)^2 + 0.256$$
$$(p = 0.221) \quad (0.005) \quad (0.006)$$
$$Adj.-R^2 = 0.482, F = 6.584\ (p = 0.015),$$
$$Turning\ point: 257.838.$$

2023

$$Y\ (SCP1/PAX) = \alpha + \beta\ (INC/PAX) + \beta\ (INC/PAX)^2 + \varepsilon,$$
$$Y = -0.118 + 0.005\ (INC/PAX) - 6.417E-06\ (INC/PAX)^2 + 0.277$$
$$(p = 0.474) \quad (0.018) \quad (0.019)$$
$$Adj.-R^2 = 0.335, F = 4.018\ (p = 0.052)*,$$
$$Turning\ point: 397.486.$$

Fig. 4 presents examples of the inverted N-shaped curve where cubic relationships demonstrate a relatively good fit. *SST* is the explanatory variable on the x-axis, and *SCP1 + 2* is the dependent variable on the y-axis, revealing an inverted N-shaped curve with two turning points. However, this combination also yields theoretical values of JPY 8,768 billion and JPY 9,098 billion for *SST*, which are unrealistically high and would take many years to achieve.

2022

$$Y\ (SCP1+2) = \alpha + \beta\ (SST) + \beta\ (SST)^2 + \beta\ (SST)^3 + \varepsilon$$
$$= 1{,}006.064 - 0.001\ (SST) + 5.152E-10\ (SST)^2 - 3.917E-17\ (SST)^3 + 308.295$$
$$(p = 0.032) \quad (0.048) \quad (0.019) \quad (0.017)$$
$$Adj.-R^2 = 0.793, F = 22.663\ (p = 1.227E-05),$$
$$Turning\ points: 1{,}227{,}828.985\ and\ 8{,}768{,}347.089.$$

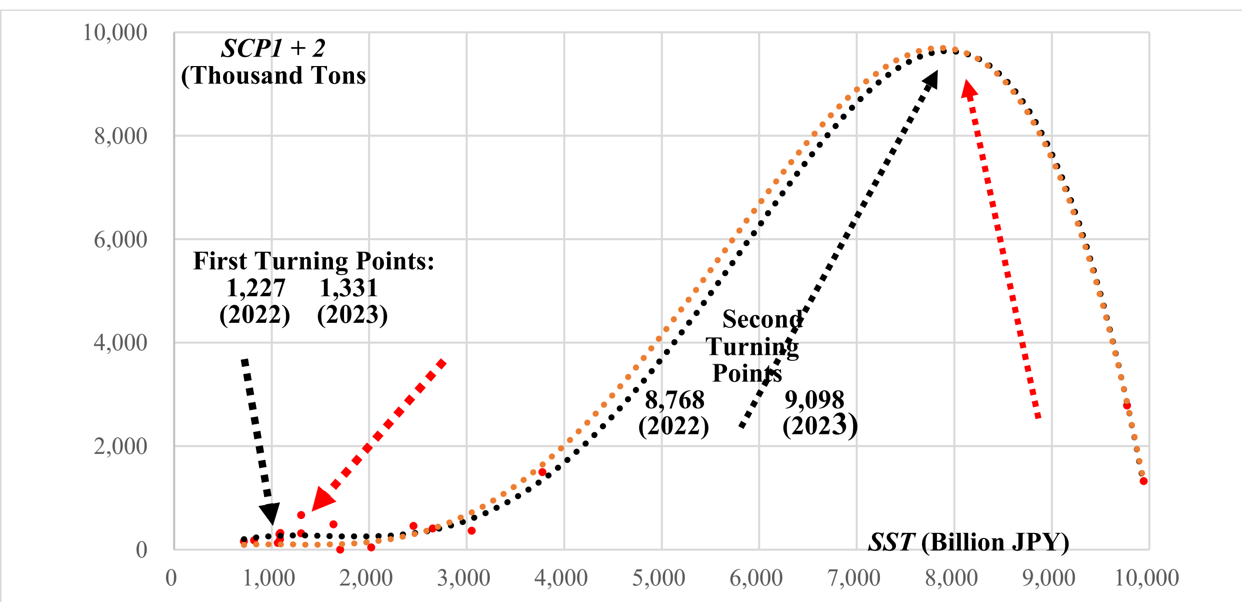


Fig. 4 *SCP1 – SST* in 2022 and 2023

$$\begin{gathered} 2023 \\ Y\,(SCP1+2) \;=\; \alpha \;+\; \beta\,(SST) \;+\; \beta\,(SST)^2 \;+ \\ \beta\,(SST)^3 \;+\; \varepsilon \\ =\; 1{,}513.370 - 0.002\,(SST) +\; 7.530E-10\,(SST)^2 \\ (p \;=\; 0.018) \quad (0.014) \qquad\qquad (0.006) \\ -\;5.518E\!-\!17\,(SST)^3 \;+\; 312.848 \\ (0.005) \\ Adj.-R^2 \;=\; 0.851, F \;=\; 23.757\;(p \;=\; 1.305E\!-\!04), \\ Turning\ points: \\ 1{,}331{,}620.279\ and\ 9{,}098{,}591.094. \end{gathered}$$

Some companies, such as Tokyo Metro and East Japan Railway, have already or almost reached the turning points (ranging from 0.068 to 0.117). This situation indicates that a *PAX/EMP* range of 0.068–0.117 could be a feasible target for other small- and mid-sized railway companies. Enhancing the (*SCP1/EMP – PAX/EMP*) or (*SCP1+2/EMP – PAX/EMP*) combination to these thresholds within the EKC framework can serve as the benchmark for achieving corporate growth while ensuring environmental conservation. This approach can also support decoupling corporate financial and transport growth from the environmental impact.

3.3. Discussion

Next, the author examines the factors contributing to the statistical significance of the analyzed results. The linear regression results in Table 2 show that the environmental impact increases with financial and transport growth, with statistically significant cases ranging from 44 (10.9%) to 49 (12.1%) during 2019–2023.

The findings show that *SCP1*, *SCP2*, and *SCP1+2* increased with increased *SAL*, *SST*, and *EMP*, with 45, 40, and 37 significant cases, respectively. These results suggest that CO_2 emissions rise with financial and transport growth.

The regression analyses provide robust empirical support for the EKC hypothesis. The quadratic regression analysis results confirm the validity of the EKC hypothesis in 8 (2.0%) to 12 (3.0%) cases over the same period (2019–2023). Moreover, the cubic regression analysis results validate the presence of an inverted N-shaped curve, with statistical significance in 4 (1.0%) to 7 (1.7%) cases during the same period.

These findings suggest that the validation of the EKC hypothesis results from the combined influence of four key factors:

- Railway companies have adopted decarbonization technologies and pursued energy efficiency in their operations;
- The growing emphasis on ESG principles by institutional investors has created additional incentives for environmental performance;
- The influence of external guidance and evaluations has driven corporate engagement in environmental conservation;
- Regulatory authorities have tightened emissions controls in line with domestic and international climate commitments.

Factor (1) contributing to validating the EKC hypothesis is that railway companies have adopted decarbonization technologies and pursued energy efficiency in their operations.

As part of the carbon emissions reduction efforts, railway operators have increasingly implemented regenerative braking systems, which convert kinetic energy into electrical energy during deceleration and introduced low-carbon rolling stock. They have also leveraged green bonds, ESG bonds, and environmental-related financing to fund energy-efficient technologies and investments in sustainable infrastructure.

This section highlights East Japan Railway and Tokyo Metro, which have reached—or nearly reached—the turning points ranging from 0.068 to 0.117. The precise econometric reasons for surpassing these turning points are not immediately evident; however, two common factors can be identified based on circumstantial evidence.

One key reason for the statistical significance of these two companies is their high *PAX/EMP* ratio, which is driven by a large passenger base. Moreover, both companies are industry leaders in adopting advanced railway technologies.

First, both companies' *PAX / EMP* ratios exceed the average of the 20 companies analyzed in this study. In 2022, Tokyo Metro's PAX / EMP ratio was 0.188, and JR East's was 0.077, compared with the industry average of 0.039.

Second, by the end of 2022, 99.9% of East Japan Railways' fleet had adopted VVVF inverters, improving energy efficiency and motor control. Notable models incorporating this technology include the E7, E233, and E235 series. Similarly, Tokyo Metro has introduced permanent magnet synchronous motors (PMSM) in its latest 17,000 and 18,000 series trains, utilizing green bonds to finance these investments. Compared with the induction motors used in the 10,000 series, these PMSM-equipped trains reduce energy consumption by approximately 20%. East Japan Railways is also conducting experimental trials of HYBARI in collaboration with Toyota Motor Corporation. This project marks a key advancement in decarbonization efforts.

These technological advancements and operational efficiencies have contributed to turning points in the 0.068–0.117 range for both (SCP1/EMP – PAX/EMP) and (SCP1+2/EMP – PAX/EMP) combinations.

Factor (2) contributing to validating the EKC hypothesis is institutional investors' growing emphasis on ESG principles, which has created additional incentives for improved environmental performance. This focus has become a critical determinant of corporate financing conditions, particularly in the context of loans, securities, and bond underwriting. Companies with insufficient ESG initiatives (especially those with weak ESG disclosures) face challenges securing funding, compelling them to enhance their ESG activities and disclosure. Compliance with ESG disclosure standards necessitates formulating and implementing strategic corporate policies and active Participation in global ESG initiatives. Sponsoring organizations' websites indicate whether companies are signatories and disclose their associated ESG ratings, prompting firms to compete with industry peers regarding ESG transparency.

The influence of the United Nations Principles for Responsible Investment (PRI) has increased (PRI, 2022).[60] Signatory investors are bound by six principles, which include the following commitments:

Table 4. Top 10 Major Shareholders of UN PRI Signatories Among the 20 Railway Corporations (as of March 2025)

Company Name	Top ten shareholders' investment ratio: %
JR Central	Nippon Life Insurance 2.54%
JR East	Nippon Life Insurance 2.12%, Mitsubishi UFJ Trust and Banking 1.32%
JR West	Nippon Life Insurance 1.61%
JR Kyushu	Taiyo Life Insurance 2.03%, Nippon Life Insurance 1.99%, Meiji Yasuda Life Insurance 1.46%
Tokyu	Dai-ichi Life Insurance 4.14%, Nippon Life Insurance 3.93%, Sumitomo Mitsui Trust Bank 3.38%, Taiyo Life Insurance 1.59%, Mitsubishi UFJ Trust and Banking 1.56%
Odakyu	Dai-ichi Life Insurance 4.79%, Nippon Life Insurance 4.66%, Meiji Yasuda Life Insurance 1.92%, Sumitomo Life Insurance 1.53%
Seibu	Development Bank of Japan 3.06%, Mizuho Trust & Banking 2.33%
Tobu	Fukoku Mutual Life Insurance 2.52%, Resona Bank 1.06%
Keio	Nippon Life Insurance 5.03%, Taiyo Life Insurance 4.80%, Sumitomo Mitsui Trust Bank 1.64%, Fukoku Mutual Life Insurance 1.57%, Dai-ichi Life Insurance 1.45%
Keikyu	Nippon Life Insurance 3.66%, Meiji Yasuda Life Insurance 2.07%,
Keisei	Nippon Life Insurance 3.80%
Metro	None
Soutetsu	Nippon Life Insurance 2.38%, Sumitomo Mitsui Trust Bank 1.87%
Meitetsu	Nippon Life Insurance 2.57%,
Kintetsu	Tokio Marine & Nichido Fire Insurance 1.02%
*Hankyu-Hanshin	Nippon Life Insurance 2.16%
Keihan	Sumitomo Mitsui Trust Bank 2.38%, Nippon Life Insurance 1.76%, Taiju Life Insurance 0.98%
Nankai	Nippon Life Insurance 2.19%, Sumitomo Mitsui Trust Bank 1.34%,
Nishi-Nippon Railroad	Nippon Life Insurance 4.24%, Meiji Yasuda Life Insurance 2.39%, Dai-ichi Life Insurance 1.33%, SOMPO 1.20%

Sources: Annual Securities Reports (2024) of Each Company [22]-[59]
* indicates two railway corporations belonging to the same group.

"We (signatory investors) will incorporate ESG issues into investment analysis and decision-making processes" (Principle 1).

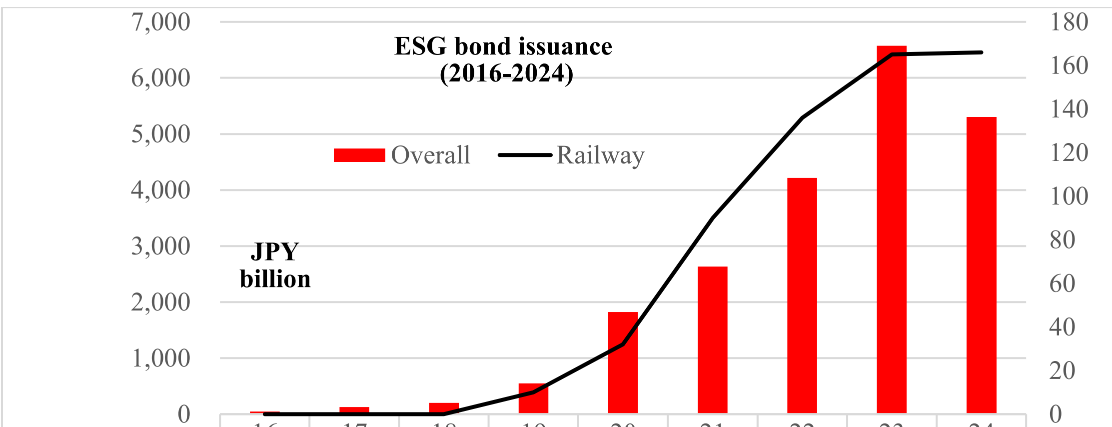
"We will seek appropriate disclosure on ESG issues by the entities in which we invest" (Principle 3).

These principles require signatory investors (such as life and non-life insurance companies, asset managers, and pension funds listed in Table 4 to make ESG-conscious investment and holding decisions, ensure transparency in their disclosures, and encourage ESG-related information disclosure from their investees.

The number of PRI signatories worldwide has increased from 63 in 2006 (its inception year) to 5,345 as of March 2024. Over the same period, these signatories' total assets under management (AUM) have also grown from USD 6.5 trillion to USD 128.4 trillion. In Japan, the number of signatory companies reached 130 by March 2024.

Table 4 presents the major shareholders of the sample firms that are PRI signatories (as of March 2025). The table highlights the influence of these signatories on ESG management within these companies. The sample firms analyzed in this study have issued ESG bonds to finance investments in energy-efficient rolling stock, eco-friendly building construction, and other ESG-related projects. The total issuance amount of the sample firms has also increased in line with the broader trend of increasing ESG bond issuance among Japanese companies; however, some firms have yet to issue such bonds.

Fig. 5 shows that based on data from the Japan Securities Dealers Association (JSDA, 2025), Japanese corporations' total ESG bond issuance was JPY 5,301 billion (USD 35.17 billion) in 2024, while the combined issuance by the sample firms was JPY 166 billion (USD 1.10 billion).[61] The available data show that since 2016, the cumulative issuance of all Japanese companies is JPY 21,469 billion (USD 142.41 billion) and JPY 599.3 billion (USD 3.98 billion) for the railway companies.



	16	17	18	19	20	21	22	23	24
Overall	45	126	201	550	1,824	2,635	4,213	6,575	5,301
Railway	0	0	0	10	32	90	136	165	166

Fig. 5 Issuance Amounts of Domestic ESG Bonds and ESG Bonds Issued by the Railway Corporations Analyzed in This Study (2016–2024, JPY Billion) [61]

Although no ESG-related shareholder proposals were found in the disclosed records of shareholder meetings for the 20 companies analyzed in this study, such proposals by financial institutions may directly affect corporate decision-making in the future.

Factor (3) contributing to validating the EKC hypothesis is the influence of external guidance and evaluations, which has driven corporate engagement in environmental conservation. Policy guidelines issued by industry associations and ESG rankings published in major business magazines have heightened competitive pressure on firms regarding their non-financial performance—particularly regarding environmental ratings—both within and across industry sectors. This study examines influential domestic initiatives, including those issued by Keidanren (Japan Business Federation) and TSE, followed by the domestic environmental rankings published by *Weekly Toyo Keizai*, and subsequently by international rankings such as the Morgan Stanley Capital International (MSCI) ESG Rankings.

Keidanren is one of Japan's most influential economic organizations, and its ESG-oriented guidelines warrant particular attention. As of April 1, 2025, its membership comprised 1,574 listed companies, including Toyota Motor Corporation. Keidanren frequently proposes economic and environmental policies and sometimes submits recommendations directly to the Prime Minister through its

Chairman. It also sets binding corporate guidelines, including provisions for membership expulsion. All the sample firms analyzed in this study are Keidanren members; thus, its regulations are binding on them. These regulations require member companies to prioritize procuring sustainable raw materials and promote recycling. Consequently, the influence of these regulations also extends indirectly to non-member companies. Tables 4 and 5 present data for only 19 companies; however, as explained in Section 3.1, Hankyu Hanshin Holdings continues to operate its railway companies as separate entities. Therefore, the total number of railway companies analyzed in this study remains at 20.

In 2017, Keidanren revised its Charter of Corporate Behavior for the Achievement of the Sustainable Development Goals (SDGs) (Keidanren, 2017) as follows:

"As responsible corporate citizens, we (member companies) will actively engage with society and contribute to its development. We are committed to promoting socially responsible initiatives through ESG-conscious management and will strive toward realizing a more sustainable society." [65]

Furthermore, Keidanren continues disseminating best ESG practices through conferences and online platforms, facilitating the exchange of ESG-related knowledge among member and non-member companies.

The Keidanren Charter is founded on a Japanese corporate philosophy: "A company is not owned solely by its shareholders but by all stakeholders—including investors, executives, employees and their families, customers, business partners, and local communities." This perspective affirms that corporations are private entities and are expected to serve as responsible public actors and engaged members of society.

The Corporate Governance Code of the TSE also states: "Listed companies should recognize that their sustainable growth and the creation of mid- to long-term corporate value result from resources and contributions provided by various stakeholders, including employees, customers, business partners, creditors, and local communities. Therefore, they should strive to collaborate appropriately with these stakeholders."

"They should disclose financial information, including their financial position and business performance, as well as non-financial information related to business strategies, management challenges, risks, and governance, under legal requirements. They should also engage in providing information beyond legal disclosure obligations. The Sustainable Development Goals (SDGs) were adopted at the United Nations Summit, and awareness has been growing that sustainability, including ESG factors, is a crucial management challenge for enhancing mid- to long-term corporate value. In light of this, Japanese companies are expected to address sustainability issues as an integral part of their management strategy."

Next, the author examines corporate ratings issued by *Weekly Toyo Keizai*, a popular economic periodical in Japan. For example, East Japan Railway and West Japan Railway are rated AAA, while Central Japan Railway is rated AA. Moreover, the author analyzes international ESG ratings, particularly those provided by MSCI. The MSCI Japan ESG Select Leaders Index, developed by MSCI, highlights companies with outstanding ESG performance. Among the 20 companies analyzed in this study, 19 (excluding Tokyo Metro, which was listed only in October 2024) have an ESG rating ranging from A to AAA (Table 5). These firms compete for investment based on their ESG performance.

Table 5. Companies' Participation (☑) and Ratings

Company Name	Keidanren	Toyo Keizai	MSCI
Former Japan National Railways (JNR)			
Central Japan	☑	AA	A
East Japan	☑	AAA	A
West Japan	☑	AAA	AA
Kyushu	☑	-	AAA
Private Railways in East Japan			
Keihin	☑	A	A
Keio	☑	AA	AA
Keisei	☑	A	A
Metro	☑	-	-
Odakyu	☑	-	A
Seibu	☑	A	AA
Soutetsu	☑	A	AA
Tobu	☑	A	A
Tokyu	☑	AAA	AAA
Private Railways in Central and West Japan			
*Hankyu-Hanshin	☑	-	AAA
Keihan	☑	AA	AA
Kintetsu	☑	AA	A
Meitetsu	☑	-	AA
Nankai	☑	-	AA
Nishi-Nippon Railroad	☑	AA	AA

Sources: Keidanren (2025), Tokyo Keizai (2024), MSCI (2025) [62]-[64]
Words such as "Holdings" and "Corporation" are omitted for simplicity.
* indicates two railway corporations belonging to the same group.

Such ESG ratings reflect a growing trend of companies adopting environmental and social strategies. These purposeful initiatives—such as green investments and decarbonization efforts—demonstrate a clear commitment to environmental conservation, irrespective of ownership structure. Whether state-owned or privately-owned, corporations function as collective entities within society. As societal interest in environmental conservation and social contributions continues to grow, internal discussions on ESG-related issues are expected to increase, prompting management and employees to adopt more ESG-oriented strategies.

In several cases observed by the author in Japanese elementary school education, students were asked to investigate and report on the environmental practices of their parents' companies. Such assignments are practical in fostering environmental awareness among children and their families. It is also common for former university classmates to meet and discuss corporate ESG rankings featured in publications like *Weekly Toyo Keizai*. These conversations often include remarks such as, "Your company is in the top ten, while ours is ranked lower—we need to improve." Such informal exchanges may help foster internal motivation for corporate sustainability efforts.

The findings indicate competition in both financial performance and non-financial environmental metrics. As the author stated in Section 2.2, ESG and SDG scores are inherently subjective; therefore, the conclusions of academic analyses that exclusively rely on them may be misleading. Nevertheless, favorable ESG ratings can enhance a company's external image and help attract highly qualified personnel. Conversely, a poor ESG reputation or low ratings because of non-compliance may undermine a company's ability to recruit top talent.

Disco Corporation, one of the most influential Japanese recruiting firms, conducts an annual survey to assess job seekers' perceptions and attitudes (Disco, 2021).[66] The 2021 survey titled "Survey Results on Job-Seekers' Company Selection and SDGs" contained a question on "the relationship between the degree of SDG commitment and job application preference," which was posed to 1,055 fourth-year university students in Japan (response rate unknown). It was found that 41.2% of the respondents stated that a company's commitment to SDGs influenced their decision to apply to that company.

Some of the respondents were unaware of the sustainability efforts of companies. As a result, it was found that personal preferences and abilities and external information sources, such as ESG and SDG ratings, often guided their career decisions. From an investor's perspective, prioritizing ESG-friendly companies is a win-win scenario, as attracting top talent enhances corporate performance.

Factor (4) contributing to validating the EKC hypothesis is the tightening of emissions controls by regulatory authorities in line with domestic and international climate commitments.

The Japanese government has pledged a 46% CO_2 reduction by 2030 (2013 baseline) and is considering a 60% target for 2035. The legislation necessary to achieve this target is still under development; therefore, in the following section, I discuss the amendments enacted in 2021. Japan's emissions reduction targets align with the objectives of the Paris Climate Agreement of 2015, which established a long-term goal of achieving net-zero emissions by 2050. The 2021 Revised Act (No. 117 of 1998) on the Promotion of Global Warming Countermeasures uses stronger language, changing the mandate from "controlling" to "reducing" GHG emissions.

For instance, Article 5 of the 2021 Revised Act stipulates, "Enterprises shall endeavor to take measures to reduce greenhouse gas emissions and cooperate with national and local government initiatives to achieve emission reductions." Article 26 mandates that "specified emitters," as designated by the Cabinet Order, must report data on their GHG emissions. These specified emitters are entities that generate substantial GHG emissions in the course of their business operations.

Furthermore, Article 75 of the 2021 Revised Act states that any company failing to submit the required report shall be subject to a civil fine of up to JPY 200,000 (approximately USD 1,360). Although the financial penalty is relatively small, compliance is incentivized through non-monetary repercussions, such as point deductions for non-compliance when applying for public tenders and potential reputational damage that could affect future business prospects.

Accordingly, Article 5 of Cabinet Order No. 272 of 2023, which enforces the 2021 Revised Act, defines "specified emitters" as companies consuming at least 1,500 kiloliters of crude oil equivalent. Although not all the sample firms analyzed in this study disclose their energy consumption data, it can be reasonably inferred that they exceed this threshold. For example, Nishi-Nippon Railroad (Nishitetsu), the smallest firm examined in terms of both the number of passengers and passenger–kilometers, reported a crude oil equivalent energy consumption of 11,230 kiloliters—well above the 1,500-kiloliter threshold (Nishi-Nippon Railroad, 2024).[45]

Furthermore, Japan's emissions trading system is expected to expand. Currently, trading between Tokyo and Saitama involves 571 facilities, including business sites and factories. As of the end of 2022, Seibu Railway and Tobu Railway are among the participants (Tokyo Metropolitan Government, 2024).[67]

The J-Credit Scheme was launched on a trial basis on the TSE in 2023, covering the entire nation, to achieve full-scale implementation by 2026. As of March 2025, 317 companies are participating in the scheme. Of the sample firms analyzed in this study, Odakyu Electric Railway and Tobu Railway participate in the Scheme (TSE, 2025). The new trading system will require companies to enhance their emissions reduction efforts further and is expected to facilitate the development of a new market.[68]

4. Conclusion and Implications

This study provides significant empirical support for the EKC hypothesis from 2019 to 2023. The quadratic regression analysis results confirm the validity of the EKC hypothesis in 12 cases (3.0%) in 2019, 8 (2.0%) in 2020, 12 (3.0%) in 2021, 11 (2.7%) in 2022, and 9 (2.2%) in 2023. Moreover, the cubic regression analysis results confirm the presence of an inverted N-shaped curve in 4 cases (1.0%) in 2019, 5 (1.2%) in 2020, 4 (1.0%) in 2021, 7 (1.7%) in 2022, and 6 (1.5%) in 2023.

These findings suggest that the validation of the EKC hypothesis results from the combined influence of four key factors:

- Railway companies have adopted decarbonization technologies and pursued energy efficiency in their operations;
- The growing emphasis on ESG principles by institutional investors has created additional incentives for environmental performance;
- The influence of external guidance and evaluations has driven corporate engagement in environmental conservation;
- Regulatory authorities have tightened emissions controls in line with domestic and international climate commitments.

Certain aspects of this study warrant further investigation in academic research, policymaking, and corporate strategic planning. Future studies should conduct a more detailed examination to elucidate the factors distinguishing significant cases under the EKC hypothesis and the inverted N-shaped test from those that do not exhibit statistical significance. Long-term verification is also required for the inherent variability and periodic updates in environmental statistics. Moreover, future studies must address corporate greenwashing—the superficial adherence to ESG principles without substantive efforts to reduce environmental impact. Furthermore, additional research is needed on the statistical significance of electricity and water consumption and industrial waste generation because available data was insufficient for a comprehensive analysis in this study. Therefore, identifying turning points for these environmental impacts remains a task for future research.

The 20 railway corporations examined in this study are expected to strengthen corporate governance, safeguard personal information, promote environmental conservation, and implement sustainable business practices. They should also contribute to regional development through job creation and tax contributions. These efforts should align with the Japanese government's and local municipalities' goals and expectations.

Nonetheless, the emergence of turning points in Fig. 2 signifies progress toward achieving corporate growth and environmental conservation—specifically, decoupling financial and transport growth from the environmental impact. Enhancing the alignment between Scope 1 CO_2 emissions per employee and passengers per employee (*SCP1/EMP – PAX/EMP*), as well as the combined Scope 1 and 2 CO_2 emissions per employee and passengers per employee (*SCP1+2/EMP – PAX/EMP*), within the identified threshold range (i.e., 0.068–0.117) can be the benchmark for empirically demonstrating the EKC hypothesis and achieving corporate growth while ensuring environmental conservation. These thresholds provide a reference for evaluating the potential for decoupling corporate financial and transport growth from environmental impacts.

The aggregated sales and emissions of the companies analyzed in this study are comparable to those of individual countries or multinational corporations. Thus, ESG-oriented management and efforts to increase *PAX*/*EMP* to the aforementioned thresholds can contribute to domestic and global environmental conservation.

Furthermore, the ESG-based and *PAX*/*EMP*-based approaches proposed in this study can help advance the research frontier in environmental economics and industrial organization theory. Therefore, the academic community should continue to explore the relationship between corporate growth and environmental conservation from diverse perspectives.

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Appendix 1. Significant Combinations of Dependent and Explanatory Variables of the EKC Hypothesis and the Inverted N-shaped Curve

combination	constant	(p)	x	(p)	x^2	(p)	x^3	(p)	St. errors	Adj.-R_2	F	(p)	1st turning points	2nd turning points
							SAL							
SCP2 – SAL-19	−385.550	0.030	1.589 E−03	8.228 E−04	−3.214 E−10	1.232 E−02			198.707	0.894	42.997	5.247 E−05	2,471,460.343	
SCP2 – SAL-20	–496.355	0.022	2.636 E−03	1.365 E−03	-8.721 E−10	1.820 E−02			214.346	0.843	30.492	9.808 E−05	1,511,142.247	
SCP2/PAX – SAL/PAX-20	−0.639	0.203	1.998 E−03	9.733 E−03	−3.464 E−07	2.424 E−02			0.589	0.516	6.864	1.547 E−02	2,883.437	
SCP2 – SAL-21	−398.413	0.050	2.044 E−03	2.501 E−03	−5.995 E−10	3.151 E−02			221.336	0.786	23.059	1.797 E−04	1,704,979.768	
SCP2/PAX – SAL/PAX-21	−0.557	0.098	1.722 E−03	1.376 E−03	−2.476 E−07	5.315 E−03			0.425	0.684	14.001	1.262 E−03	3,479.019	
SCP2/PAX – SAL/PAX-22	−0.505	0.067	1.459 E−03	8.579 E−04	−2.088 E−07	3.463 E−03			0.354	0.715	16.039	7.580 E−04	3,493.490	
SCP2 – SAL-23	−369.768	0.045	1.495 E−03	1.845 E−03	−3.244 E−10	2.888 E−02			225.849	0.821	28.590	7.308 E−05	2,304,903.854	
SCP1+2/PAX – SAL/PAX-21	−0.341	0.215	1.496 E−03	2.439 E−04	−1.528 E−07	1.610 E−02			0.395	0.785	33.934	1.755 E−06	4,895.396	
SCP2 – SAL-20	725.402	0.053	−4.250 E−03	3.971 E−02	8.565 E−09	6.286 E−03	−3.367 E−15	3.638 E−03	129.976	0.942	60.776	7.551 E−06	248,122.624	1,695,633.662
							INC							
SCP1 – INC-19	−120.426	0.422	0.010	0.014	−2.225 E−08	0.020			294.325	0.442	4.968	0.040	215,177.999	
SCP1/PAX – INC/PAX-22	−0.198	0.221	0.009	0.005	−1.731 E−05	0.006			0.256	0.482	6.584	0.015	257.838	
SCP1 – INC-23	−330.607	0.135	0.011	0.015	−2.545 E−08	0.023			336.494	0.366	4.468	0.041	219,087.492	
SCP2 – INK-19	−16.649	0.926	0.012	0.011	−2.249 E−08	0.043			358.994	0.722	10.399	0.006	275,569.826	
SCP1/PAX – INC/PAX-23	−0.118	0.474	0.005	0.018	−6.417 E−06	0.019			0.277	0.335	4.018	0.052	397.486	
SCP2 – INC-22	−260.096	0.070	0.019	5.606 E−04	−5.535 E−08	8.459 E−03			212.701	0.813	27.165	9.077 E−05	173,809.654	
SCP2 – INK-19	−146.202	0.356	0.022	6.716 E−05	−4.353 E−08	5.419 E−04			384.293	0.729	22.480	4.256 E−05	247,432.660	
SCP1+2 – INC-22	−217.455	0.371	0.024	0.006	−7.280 E−08	0.047			487.369	0.482	8.904	0.003	161,509.911	
SCP1+2/PAX – INC/PAX-22	0.015	0.383	0.001	0.018	−1.429 E−06	0.021			0.034	0.228	3.508	0.056	244.642	
SCP1+2 – INC-23	−518.772	0.096	0.023	0.002	−4.662 E−08	0.006			467.415	0.666	12.980	0.002	247,667.219	
SCP1 – INC-19	241.032	6.130 E−05	−0.010	4.170 E−05	1.370 E−07	8.294 E−07	−2.821 E−13	2.776 E−07	43.380	0.988	272.891	1.302 E−07	37,527.326	323,842.988
SCP1/PAX – INC/PAX-22	0.263	0.042	−0.008	0.041	1.034 E−04	9.657 E−04	−1.888 E−07	3.144 E−04	0.127	0.873	28.586	6.231 E−05	36.300	365.130

Appendix 1. Significant combinations of dependent and explanatory variables (continued)

combination	constant	(p)	x	(p)	x^2	(p)	x^3	(p)	St. errors	Adj.-R_2	F	(p)	1st turning points	2nd turning points
INC														
SCP1 – INC-23	474.094	6.316 E−05	−0.019	1.031 E−05	2.057 E−07	3.130 E−07	−4.156 E−13	1.064 E−07	69.114	0.973	146.621	5.872 E−08	45,453.823	329,872.113
SCP2/PKM – INK/PKM-19	0.081	0.012	−0.073	0.034	0.025	0.028	−0.002	0.028	0.014	0.325	2.607	1.338 E−01	1.469	6.995
SCP2 – INC-22	317.867	0.028	−0.018	0.028	4.550 E−07	7.896 E−04	−1.604 E−12	3.440 E−04	106.205	0.953	83.007	7.049 E−07	20,196.136	189,113.004
SST														
SCP1/PAX – SST/PAX-19	−0.450	0.037	3.662 E−04	0.002	−1.952 E−08	0.002			0.235	0.665	10.948	0.005	9,379.045	
SCP1/PAX – SST/PAX-20	−0.506	0.027	2.753 E−04	9.431 E−04	−9.381 E−09	0.001			0.250	0.659	11.630	0.003	14,673.887	
SCP1/PAX – SST/PAX-21	−0.442	0.021	2.753 E−04	4.288 E−04	−1.039 E−08	5.359 E−04			0.232	0.672	13.301	0.002	13,243.399	
SCP1/PAX – SST/PAX-22	−0.420	0.022	2.880 E−04	5.987 E−04	−1.281 E−08	7.169 E−04			0.211	0.650	12.140	0.002	11,238.142	
SCP1/PAX – SST/PAX-23	−0.382	0.029	2.773 E−04	7.981 E−04	−1.305 E−08	9.638 E−04			0.206	0.630	11.213	0.003	10,623.995	
SCP1+2/PAX – SST/PAX-19	−0.257	0.217	4.561 E−04	1.496 E−04	−1.716 E−08	0.003			0.290	0.811	35.365	3.362 E−06	13,285.247	
SCP1+2/PAX – SST/PAX-21	−0.410	0.157	4.632 E−04	1.211 E−04	−1.312 E−08	0.002			0.417	0.761	29.642	4.162 E−06	17,651.179	
SCP1+2/PAX – SST/PAX-22	−0.029	0.140	3.168 E−05	2.481 E−04	−1.429 E−09	2.673 E−04			0.026	0.551	11.444	9.590 E−04	11,087.019	
SCP1+2/PAX – SST/PAX-23	−0.405	0.166	4.364 E−04	0.001	−1.451 E−08	0.012			0.358	0.803	25.517	1.181 E−04	15,041.255	
SCP1 – SST-19	615.464	0.004	−8.498 E−04	0.001	3.166 E−10	3.050 E−04	−2.431 E−17	2.296 E−04	135.299	0.882	25.960	3.628 E−04	1,341,943.864	8,684,074.882
SCP1 – SST-20	725.400	0.011	−0.001	0.006	3.870 E−10	0.002	−2.926 E−17	0.002	196.212	0.753	12.178	0.002	1,382,096.461	8,819,057.031
SCP1 – PAX-21	0.277	0.081	−1.730 E−04	0.055*	5.269 E−08	7.200 E−04	−1.913 E−12	1.940 E−04	0.109	0.928	52.421	5.052 E−06	1,641.183	18,363.425
SCP1/PAX – SST/PAX-22	0.301	0.066	−2.263 E−04	0.037	7.291 E−08	7.828 E−04	−3.078 E−12	2.433 E−04	0.101	0.919	46.407	8.447 E−06	1,552.045	15,790.230
SCP1/PAX – SST/PAX-23	0.298	0.085	−2.247 E−04	0.056	7.284 E−08	1.849 E−03	−3.225 E−12	6.025 E−04	0.110	0.896	35.403	2.605 E−05	1,542.198	15,059.318
SCP2 – SST-22	639.431	0.076	−8.359 E−04	8.432 E−02	3.660 E−10	0.025	−2.866 E−17	0.020	187.556	0.855	24.578	1.140 E−04	1,141,990.811	8,514,454.481
SCP1+2 – SST-19	488.009	0.020	−5.986 E−04	0.018	3.629 E−10	1.252 E−04	−3.030 E−17	4.849 E−05	209.247	0.920	61.957	5.889 E−08	824,773.616	7,983,887.984
SCP1+2 – SST-20	789.894	4.048 E−04	−1.060 E−03	2.280 E−04	5.018 E−10	4.508 E−06	−4.015 E−17	2.502 E−06	168.901	0.940	90.326	2.123 E−09	1,056,210.816	8,332,082.492

SCP1+2 – SST-21	863.117	0.014	−0.001	0.021	4.835 E−10	0.003	−3.836 E−17	0.002	264.747	0.833	30.953	1.139 E−06	1,100,418.253	8,403,837.502

Appendix 1 Significant combinations of dependent and explanatory variables (continued)

combination	constant	(p)	x	(p)	x²	(p)	x³	(p)	St. errors	Adj.−R ²	F	(p)	1st turning points	2nd turning points
SST														
SCP1+2 – SST-22	1,006.064	0.032	−0.001	0.048	5.152 E−10	0.019	−3.917 E−17	0.017	308.295	0.793	22.663	1.227 E−05	1,227,828.985	8,768,347.089
SCP1+2 – SST-23	1,513.370	0.018	−0.002	0.014	7.530 E−10	0.006	−5.518 E−17	0.005	312.848	0.851	23.757	1.305 E−04	1,331,620.279	9,098,591.094
EPS														
SCP1/EMP – EPS/EMP-23	0.025	0.003	−4.567	0.019	278.478	0.025	−4564.956	0.032	0.005	0.327	2.942	0.091	0.008	0.041
TSR														
None														
EMP														
SCP2/PAX – EMP/PAX-19	−0.311	0.412	0.041	0.018	−1.836 E−04	0.028			0.475	0.426	4.717	0.044	111.233	
SCP2/PKM – EMP/PKM-19	0.005	0.416	0.017	0.004	−0.001	0.015			0.008	0.783	19.009	0.001	8.705	
SCP2/PAX – EMP/PAX-20	−0.593	0.201	0.045	0.006	−1.538 E−04	0.010			0.580	0.531	7.234	0.013	147.115	
SCP2/PAX – EMP/PAX-21	−0.571	0.099	0.045	0.001	−1.557 E−04	0.004			0.439	0.662	12.759	0.002	144.648	
SCP2/PKM – EMP/PKM-21	0.008	0.347	0.015	0.005	−0.001	0.051			0.010	0.857	36.846	2.436 E−05	13.924	
SCP2/PAX – EMP/PAX-22	−0.494	0.151	0.045	0.004	−1.813 E−04	0.008			0.443	0.554	8.439	0.007	123.416	
SCP2/PKM – EMP/PKM-22	0.008	0.158	0.013	0.006	−0.001	0.054*			0.008	0.834	31.112	5.089 E−05	11.945	
SCP2/PAX – EMP/PAX-23	−0.503	0.132	0.049	0.004	−2.068 E−04	0.008			0.418	0.575	9.128	0.006	117.853	
SCP2/PAX – EMP/PAX-23	−0.503	0.132	0.049	0.004	−2.068 E−04	0.008			0.418	0.575	9.128	0.006	117.853	
SCP1+2/PAX – EMP/PAX -20	−0.260	0.454	0.035	0.003	−8.967 E−05	0.029			0.522	0.629	15.384	2.325 E−04	195.405	
SCP1+2/PAX – EMP/PAX -21	−0.216	0.383	0.035	1.902 E−04	−8.632 E−05	0.011			0.403	0.776	32.267	2.427 E−06	201.751	
SCP2/PAX – EMP/PAX-20	0.539	0.332	−0.032	0.312	0.001	0.043	−3.612 E−06	0.024	0.439	0.731	10.969	0.003	15.509	188.286
SCP2/PAX – EMP/PAX-21	0.424	0.276	−0.027	0.261	0.001	0.017	−3.900 E−06	0.008	0.307	0.836	21.321	1.994 E−04	13.043	175.058
SCP2/PAX – EMP/PAX-22	0.477	0.271	−0.038	0.228	0.001	0.028	−6.085 E−06	0.016	0.333	0.748	12.849	0.001	13.413	155.912
SCP2/PAX – EMP/PAX-23	0.366	0.387	−0.033	0.333	0.002	0.042	−7.117 E−06	0.025	0.328	0.738	12.294	0.002	10.584	144.463

Appendix 1 Significant combinations of dependent and explanatory variables (continued)

combination	constant	(p)	x	(p)	x^2	(p)	x^3	(p)	St. errors	Adj.-R_2	F	(p)	1st turning points	2nd turning points
PAX														
SCP1/EMP – PAX/EMP-19	0.001	0.637	0.238	0.030	−1.021	0.021			0.004	0.406	4.417	0.051	0.117	
SCP1/EMP – PAX/EMP-20	−1.247 E−05	0.997	0.335	0.030	−2.126	0.023			0.004	0.340	3.839	0.062	0.079	
SCP1/EMP – PAX/EMP-21	4.795 E−04	0.886	0.287	0.047	−1.744	0.035			0.004	0.254	3.040	0.093	0.082	
SCP1/EMP – PAX/EMP-23	0.001	0.821	0.222	0.049	−1.049	0.036			0.004	0.254	3.039	0.093	0.106	
SCP1+2/EMP – PAX/EMP-21	0.016	0.003	0.391	0.058*	−2.852	0.020			0.008	0.287	4.627	0.026	0.068	
SCP1+2/EMP – PAX/EMP-22	0.016	0.002	0.345	0.041	−2.161	0.013			0.007	0.314	5.116	0.019	0.080	
SCP1/EMP – PAX/EMP-20	0.008	0.017	−0.460	0.062*	15.328	0.008	−82.294	0.004	0.002	0.755	12.303	0.002	0.015	0.124
SCP1/EMP – PAX/EMP-21	0.010	0.011	−0.544	0.035	15.528	0.005	−77.512	0.003	0.003	0.708	10.712	0.003	0.018	0.134
SCP1/EMP – PAX/EMP-22	0.010	0.011	−0.495	0.033	11.983	0.006	−51.248	0.003	0.003	0.693	10.032	0.003	0.021	0.156
SCP1+2/EMP – PAX/EMP-23	0.011	0.015	−0.473	0.041	10.684	0.007	−41.348	0.004	0.003	0.687	9.767	0.003	0.022	0.172
PKM														
SCP1/EMP – PKM/EMP-19	0.001	0.637	0.238	0.030	−1.021	0.021			0.004	0.406	4.417	0.051	0.117	
SCP2 – PKM-19	−21.999	0.846	0.032	0.001	−1.507 E−07	0.014			237.370	0.848	28.934	2.176 E−04	105,286.359	
SCP2/EMP – PKM/EMP-20	−0.006	0.438	0.096	0.005	−0.066	0.006			0.007	0.506	6.632	0.017	0.729	
SCP2 – PKM-21	−43.305	0.638	0.046	2.488 E−04	−3.448 E−07	0.003			196.798	0.831	30.492	5.549 E−05	66,634.763	
SCP2/EMP – PKM/EMP-21	−0.002	0.748	0.069	0.016	−0.042	0.020			0.007	0.355	4.304	0.045	0.811	
SCP2 – PKM-22	−36.462	0.640	0.035	1.214 E−04	−2.126 E−07	0.003			174.090	0.875	43.014	1.225 E−05	83,059.696	
SCP2 – PKM-23	−60.827	0.525	0.037	1.815 E−04	−2.182 E−07	0.003			213.892	0.840	32.451	4.242 E−05	84,450.913	
SCP1+2/EMP – PKM/EMP-20	0.001	0.920	0.082	0.010	−0.053	0.016			0.009	0.297	4.599	0.028	0.774	

Sources: The author's calculations are based on each company's environmental reports/ESG data.
As a guide to interpreting the table, for example, *SCP2–SAL-19* denotes a statistically significant combination of Scope 2 CO_2 emissions (*SCP2*) and net sales (*SAL*) in 2019.
To ensure rigour, the data is presented to three digits after the decimal point. If zero continues after the third digit (e.g., 0.0003585504), it is not presented as 0.000 but as an exponent, 3.586E−04. The amount exceeding one million yen, i.e., seven digits, is also indicated as an exponent.
*The value is deemed to meet the requisite level of significance.