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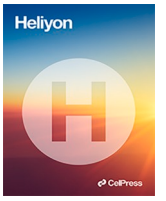

Research article

# Exploring the impact of green logistics practices and relevant government policy on the financial efficiency of logistics companies

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ABSTRACT

The coexistence of carbon neutrality and capitalism can be realized if environmentally friendly management is proven to enhance profitability. The focus of green logistics practices (GLPs) is on maximizing energy efficiency in logistics services, potentially leading to cost reductions for companies. Such practices can be supported through public reports, such as Environmental, Social, and Governance (ESG) reports, and government policies, including government certification. The primary objective of this study is to investigate whether the financial efficiency of logistics companies can be improved through the implementation of GLPs and a relevant government policy. To achieve this objective, a two-stage analysis was conducted using Data Envelopment Analysis - Slack-Based Measure (DEA-SBM) and Tobit regression analysis. The DEA-SBM was employed to assess whether the financial efficiency of logistics companies adopting GLPs and a relevant government policy was superior to that of companies not adopting such practices. Additionally, Tobit regression analysis was employed to analyze the effects of GLPs, ESG reports, and a government policy on the financial efficiency of logistics companies. The findings of the study indicate the necessity for collaboration between the private and public sectors to implement GLPs in a financially positive manner. In conclusion, the research demonstrated that the implementation of GLPs, coupled with public disclosure through ESG reports or equivalents and a government policy, had a positive impact on the financial efficiency of logistics companies.

## 1. Introduction

Global warming and climate change pose significant threats to humanity, leading many stakeholders to demand solutions and actions to address these issues [1]. In response, the logistics industry has recognized the importance of environmental sustainability as a necessary precondition [2–5]. To achieve this, logistics companies have implemented environmentally friendly management strategies known as green logistics practices(GLPs), which are critical for sustainable operations [3,5–7].

Major third-party logistics service providers worldwide have also ensured environmental sustainability to meet the growing demand for eco-friendly operations [8]. Logistics companies have generated environmental and economic benefits from their various sustainable logistics activities [9]. Furthermore, governments have made policies to promote and support GLPs in the logistics industry

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[10].

Given that the logistics industry consumes a significant amount of energy compared to other industries [6,11,12], negative environmental effects such as greenhouse gas emissions are a natural consequence [10,13]. As a result, ensuring environmental sustainability has become an unavoidable issue for logistics companies [7,14,15]. Logistics companies have been regarded as playing a critical role in promoting the environmental sustainability of the logistics industry since they are involved in the physical networks of the industry [16]. Yet, profit-driven entities within the capitalist framework frequently demonstrate a reluctance to embrace initiatives that may not yield or promise financial returns.

Consequently, there is an escalating demand for research examining logistics companies and their adoption of GLPs. This increased interest stems from the critical need to find strategic solutions that allow these companies to navigate the intersection between profit motives and environmental responsibilities, especially in pressing global warming issues.

## 2. Literature review and research gap

Recent research has highlighted the potential benefits for companies that adopt management strategies focused on environmental considerations to secure their competitive advantage [17–19]. This has led to increased attention to green management practices. According to a natural resource-based view (NRBV), the environment should be considered a critical factor in corporate management strategy [17]. It was also suggested that economic activities that were not environmentally sustainable could not be sustained, and therefore the ability to engage in environmentally sustainable business activities would be the foundation of a company's competitive advantage strategy [17]. While the NRBV initially focused on the manufacturing industry, the emphasis on the relevance to the logistics industry was raised, given its responsibility for environmental protection and energy consumption [6].

Compared to the manufacturing industry, the service industry has received relatively little attention in studies on environmental sustainability [20,21]. Similarly, research on the environmental sustainability of the logistics industry, which falls under the service industry, has been limited despite its negative environmental effects [2,22–25]. Although the role of logistics companies is critical for the environmental sustainability of the logistics industry [23], only a few studies have investigated their environmental sustainability [12,26]. Moreover, research on the relationship between GLPs and the competitiveness of logistics companies has been insufficient [6,8,27], and there has been little investigation into the effects of policies promoting and supporting green logistics [10].

One of the representative GLPs of logistics companies is the optimization of truck routing and scheduling, which helps reduce their energy consumption and eventually leads to a decrease in greenhouse gas emissions [28–31]. The economic factor was perceived as a key barrier to adopting GLPs [32]. Environmental sustainability could be adopted when it could act as an internal driver to compress operation costs and increase profitability for logistics companies [33]. The efficiency gains derived from these sustainable activities are closely tied to reduced energy consumption, resulting in cost savings that can enhance overall financial efficiency. Economic benefits from the environmental sustainability of logistics companies could come from the reduction of material costs and energy consumption, which might lead to better economic and financial performance [34]. Therefore, the viability of GLPs within logistics companies hinges on their positive impact on financial performance.

Paradoxically, there has been a scarcity of comprehensive research approaches to validate the influence of GLPs on the financial performance of logistics companies. Consequently, there is a pressing need for research to scrutinize the impact of GLPs on financial efficiency, along with government policies designed to support these environmentally friendly initiatives. This research aims to explore the impact of GLPs and relevant government policy on the financial efficiency of logistics companies. It could offer insights into the seamless integration of profit-driven objectives and GLPs within logistics companies, thereby simultaneously fostering economic success and environmental sustainability.

## 3. Methods

### 3.1. Research framework

The two-stage analysis methodology, utilizing DEA analysis to derive the efficiency of the subject and Tobit analysis to investigate the factors influencing efficiency, has been widely applied across various industries. The efficiency of major airports in Southeast Asia was analyzed using DEA-SBM and subsequently conducted a secondary analysis of the factors affecting efficiency through Tobit regression analysis [35]. The impact of smart port design on maritime transport efficiency was explored using a three-step modeling procedure involving DEA-Tobit regression analysis [36].

The potential for information communication technology to enhance the sustainability of smart tourism destinations was examined by employing a two-stage analysis methodology that incorporated the DEA-Tobit regression model [37]. The efficiency of China's green economy was evaluated by using the Super-efficient DEA model and analyzed the impact of environmental regulations on green economic efficiency through Tobit regression analysis [38].

Similarly, in various industries such as aviation, tourism, ports, and the environment, DEA has been used to analyze efficiency related to the industry or relevant issues as the first stage analysis, and Tobit regression analysis has been employed to examine the factors influencing efficiency as the second stage. This research aims to analyze the financial efficiency of Korean logistics companies, differentiate them based on GLPs, and analyze the impact of GLPs including related government policy on efficiency. Therefore, the present research proceeded with the DEA-Tobit two-stage analysis which involved two types of analysis.

First, a comparative analysis of financial efficiency was conducted using Data Envelopment Analysis (DEA)- Slack-based measure (SBM) to observe the differences in financial efficiency between groups that have implemented GLPs and those that have not. Second,

an analysis of the factors that influence the efficiency was conducted using Tobit regression analysis based on the DEA-SBM results, to verify the effect of GLPs on financial efficiency. Figure 1 states the research framework.

### 3.2. Research method (1): DEA-SBM

Data Envelopment Analysis (DEA) is a non-parametric assessment model used to evaluate the relative efficiencies of decision-making units (DMUs). DEA models are typically categorized into CCR (Charnes, Cooper, and Rhodes) and BCC (Banker, Charnes, and Cooper) models, based on whether scale returns are variable. The CCR model measures the technical efficiency score of DMUs under the constant return to scale (CRS) assumption [39], while the BCC model measures the pure technical score of DMUs under the variable returns to scale (VRS) assumption [40]. However, these two models are angle-based radial models, which may overestimate the efficiency of DMUs with input redundancy and output shortfall.

To resolve this problem, the DEA-SBM (Slack Based Measure) model was proposed [41]. The DEA-SBM model is a non-radial and non-angle model that considers input and output slack variables, making it suitable for measuring efficiencies when inputs and outputs may not change proportionally [42].

A set of n DMUs has $k$ inputs and $l$ outputs. DMU $j$ with the $i$ th input and the $r$ th output is denoted as $x_{ij}$ $(i = 1, \ldots, k\,; j = 1, \ldots, n)$ and $y_{rj}$ $(r = 1, \ldots, l\,; j = 1, \ldots, n)$ respectively. The model for DMU $m$ is as below. The symbol ρ* represents the efficiency value between 0 and 1, and a DMU is considered efficient if ρ* equals 1. In the equation, $x_{ij}$ and $y_{rj}$ represent input and output variables, respectively, where $i$ and $r$ are the number of variables. The symbols $s_i^-$ and $s_r^+$ indicate input excess and output shortfall. Finally, $\lambda$ is the constraint of input and output.

$$\min \rho^* = \frac{1 - \left(\frac{1}{k}\right) \sum_{i=1}^{k} s_i^- \Big/ x_{im}}{1 + \left(\frac{1}{l}\right) \sum_{r=1}^{l} s_r^+ \Big/ y_{rm}}, 0 < \rho \leq 1$$

*subject to*:

$$x_{im} = \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^-, i = 1, \ldots, k$$

$$y_{rm} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+, r = 1, \ldots, l$$

$$\lambda_j \geq 0, j = 1, \ldots, n$$

$$s_i^- \geq 0, i = 1, \ldots, k$$

$$s_r^+ \geq 0, r = 1, \ldots, l$$

### 3.3. Research method (2): Tobit regression

The Tobit regression model is known as an appropriate regression model for describing the causality of censored or truncated data, which has limited dependent and independent variables [43]. DEA-SBM analysis results range from 0.0 to 1.0, but they are considered truncated. Therefore, the Tobit regression model is suitable for the second-stage analysis of DEA-SBM results [35–38]. The Tobit regression model can be expressed as the following linear equation.

$$y_i^* = \beta_0 + \beta_i x_i + \varepsilon_i, i = 1, 2, \cdots, \mathcal{N}$$

$$\varepsilon_i \tilde{} \left(N, \sigma^2\right).$$

$$y_i = \begin{cases} y^* \text{ if } y_i^* < \theta \\ \theta \text{ if } y_i^* \geq \theta \end{cases}$$

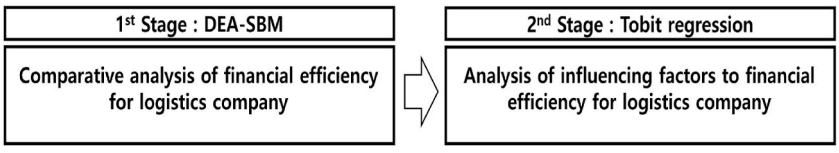


**Fig. 1.** Research framework.

In the Tobit regression model, $y_i^*$ represents the dependent variable which is $y^*$ when it is observed for values below $\theta$ and censored otherwise. $x_i$ represents an independent variable that influences the efficiency score. $\beta_i$ is a coefficient that reflects the relationship between $x_i$ and $y_i^*$. $\varepsilon_i$ is the error term under a normal distribution. In our analysis, a regression model is as below.

$$y_i^* = \beta_0 + \gamma s_i + \sum_j \beta_j x_{ij} + \varepsilon_i, i = 1, 2, \cdots, N$$

$$\varepsilon_i \sim (N, \sigma^2)$$

$$y_i = \begin{cases} y^* \ if \ y_i^* < 1 \\ 1 \ if \ y_i^* \geq 1 \end{cases}$$

$y_i$ is the efficiency score for logistics company $i$ and $y_i^*$ is the latent variable. $\gamma$ is the coefficients for the control variable and $\beta_j$ are the coefficients for influencing factor $j$. $s_i$ is the control variable and $x_{ij}$ influencing factors. $\varepsilon_i$ is the error term.

### 3.4. Data construction

Data used for the DEA-SBM analysis was collected from the financial statements of Korean logistics companies that had been certified as excellent total logistics service providers by the Korean government. Focusing on these certified companies was important to ensure representativeness in the research analysis. As of 2021, there were 16 certified companies [44]. The research period spanned from 2010, when green practices were first introduced to Korean logistics companies, to 2021. The total number of decision-making units (DMUs) candidates included in the analysis was 191, with the first company being certified in 2011. However, 8 candidates were eliminated because they had negative values in operating income, which were not appropriate as variables for DEA-SBM analysis. Table 1 states general information of data.

Korean logistics companies have implemented GLPs to address climate change mitigation. These practices primarily aim to reduce greenhouse gas emissions through efficient management of vehicles and buildings in logistics activities, as well as through the introduction of greener energy sources such as hydrogen. The focus of GLPs among Korean logistics companies is to achieve a reduction in greenhouse gas emissions by improving energy efficiency in logistics activities.

Since 2012, the Korean government has been certifying excellent green logistics companies to promote the adoption of GLPs. These certified companies receive incentives such as loan support and preferential occupancy rights for logistics facilities and could increase their publicity with the certification. This certification policy has been the only government initiative for promoting GLPs among logistics companies in Korea.

The companies were divided into groups based on the level of their GLPs, which included public reports including environmental aspects, and participation in government certification for GLPs. The groups of DMUs were largely divided into those conducting GLPs and those that were not (non-GLPs). The group conducting GLPs was further subdivided into four categories. The first category consisted of logistics companies conducting GLPs without both public reports and government certification for green logistics (GLP1). The second category included logistics companies conducting GLPs with public reports (GLP2). The third category consisted of logistics companies conducting GLPs with green logistics certification from the government (GLP3). The last category included logistics companies conducting GLPs with both reports and government certification (GLP4). Table 2 states the details of the DMU groups for this research.

### 3.5. DEA-SBM variables

Appropriate input and output variables are critical for DEA-SBM analysis. In terms of input variables, assets, cost of sales, sales and general administrative expenses (SG&A) were selected. Logistics companies providing total logistics services have tangible and intangible assets, including warehouses, terminals, trucks, software programs, and deposits on land or other infrastructure. Managing these assets is one of the keys to logistics companies' efficiency. The cost of sales is most of the operating expense, including variable costs such as fuel, utilities, and license fees. SG&A includes salaries, employee benefits, advertisement costs, etc. Both costs of sales and SG&A need to be optimized while offering efficient logistics services. In this sense, assets, and operating costs, which include the cost of sales and SG&A were used as input variables for research of DEA analysis in the field of logistics [45–47]. DEA research for other fields selected assets and operating costs as input variables as well [48,49].

In terms of output variables, sales, and operating income were selected. Sales are the intuitive outcome of business activity, so it can be used to measure the influence of GLPs with the improvement in customer perception. Sales were used as an output variable for DEA analysis in other fields [48]. The operating income is the outcome of sales deducting the cost of sales and SG&A, which can be used to

**Table 1**
General information of data.

| Research sample | Certified logistics companies in South Korea |
|---|---|
| Research period | 2010~2021 (12 years) |
| Number of DMUs | 183 |

**Table 2**
Classification of DMU groups.

| Classification | | No. | % |
|---|---|---|---|
| non-GLPs(Green Logistics Practices) | | 105 | 57.4 |
| GLPs(Green Logistics Practices) | | 78 | 42.6 |
| GLP1 | GLPs without public reports and government green certification | 23 | 12.6 |
| GLP2 | GLPs + Public reports | 5 | 2.7 |
| GLP3 | GLPs + Government green certification | 32 | 17.5 |
| GLP4 | GLPs + Public reports + Government green certification | 18 | 10.8 |
| Total | | 183 | 100.0 |

measure how efficiently logistics companies optimize the use of fuels and labor with GLPs. In this regard, operating income was used as an output variable for research of DEA analysis in the field of logistics [45,47]. Table 3 shows the detail of input and output variables using DEA analysis in the forementioned research.

Table 4 shows descriptive statistics of input and output variables of the Korean logistics companies for this research. The data was sourced from the financial statements of each logistics company through the Korean official electronic disclosure system, DART.

### *3.6. Tobit regression variables*

The control variable selected for this study was the sales of Korean logistics companies, which can be used to represent the size of the companies. Sales were used as a control variable to analyze the effects of green supply chain management on the financial performance of Finnish logistics service providers [50]. The independent variables in this study were the types of GLPs adopted by Korean logistics companies. Specifically, elements of GLPs including ESG reports, and government certification were transformed into binary dummy variables. Finally, the dependent variable used in the analysis was the DEA-SBM score of each DMU.

## 4. Results analysis

### *4.1. Efficiency analysis*

Table 5 presents the results of the DEA-SBM analysis. The DEA score for non-GLPs was 0.433, while that of GLPs was 0.397. The number of efficient DMUs was 21 for the non-GLPs and 6 for the GLPs. There could be several reasons why the efficiency of non-GLPs was better than that of GLPs. First, significant investments normally required for GLPs [51,52] could lead to lower efficiency of the GLPs group. It could mean the cost of GLPs was higher than expected as well. Second, GLPs were not done in the right ways, so it appeared for the non-GLPs to be more efficient. Lastly, it could be possible that the GLPs group would need more time to realize their economic benefits from GLPs. Because it has been regarded that economic benefits from GLPs could be achieved in the long-term perspectives [53,54]. Therefore, the quality of GLPs needed to be scrutinized whether they were conducted in the right ways with further analysis.

The categories of GLPs shall be considered to identify the reasons for the inefficiency of the GLPs group. GLPs could be divided into four sub-groups. ESG reports and government certification could act differently to motivate logistics companies to conduct their GLPs. In this sense, the efficiency scores of the GLPs subgroups showed a different perspective on the GLPs of Korean logistics companies.

The scores of GLP1 (0.254), GLP2 (0.167), and GLP3 (0.405) were lower than the total average (0.418) while that of GLP4 (0.632) was higher than the average and the highest among all groups. The number of efficient DMUs in subgroups was 2 for GLP 3 and 4 for GLP 4. The efficiency score got better when GLPs were done with government certification. The score was the best when a government policy like the government certification and public reports were combined with GLPs.

The results from the DEA-SBM analysis revealed that the implementation of GLPs alone did not yield better financial efficiency for Korean logistics companies. Interestingly, those companies incorporating both public reporting and a government certification achieved the highest efficiency scores. It suggested that verified GLPs could positively influence financial efficiency [55]. Based on these results, a second-stage analysis was needed to empirically clarify which types of GLPs should be done by logistics companies to realize financial efficiency.

**Table 3**
Reference of input and output variables.

| Input Indicators | Output Indicators | Reference |
|---|---|---|
| Assets, Operating expenses, Current liabilities, General administrative and investment | Operating income, Efficiency, Effectiveness and performance | [45] |
| Account receivables, Salaries and wages (including fringe benefits) of employees, Operating expenses other than salaries and wages, and Property and equipment | Operating income | [46] |
| Assets, Operating expenses, Current liabilities, Salaries and wages | Operating income | [47] |
| Advertising and promotion expenses, Manager experience (salaries) and the Number of employees | Sales and Customer satisfaction | [48] |
| the Number of employees, Total assets, and Total operating expenses | Revenues and a Web metric | [49] |

**Table 4**
Descriptive statistics of input and output variables.

| Variable | (Unit: Thousand USD) | | | | |
|---|---|---|---|---|---|
| | Mean | SD | Median | Minimum | Maximun |
| **<Input>** | | | | | |
| Assets | 953,076 | 1,450,381 | 383,218 | 24,994 | 7,736,162 |
| Cost of sales | 1,161,647 | 2,162,583 | 392,500 | 27,655 | 12,622,217 |
| S&GA | 53,271 | 82,430 | 19,430 | 2436 | 415,051 |
| **<Output>** | | | | | |
| Sales | 1,260,966 | 2,331,860 | 426,991 | 43,261 | 13,517,463 |
| Operating income | 46,048 | 99,033 | 13,631 | 312 | 688,129 |

*Assume that 1USD was KRW1,300.

**Table 5**
DEA-SBM result.

| Classification | DEA Score | No. of Efficient DMUs |
|---|---|---|
| non-GLPs(Green Logistics Practices) | 0.433 | 21 |
| GLPs(Green Logistics Practices) | 0.397 | 6 |
| GLP1: GLPs without ESG report or government cert. | 0.254 | 0 |
| GLP2: GLPs with ESG report | 0.167 | 0 |
| GLP3: GLPs with government cert. | 0.405 | 2 |
| GLP4: GLPs with ESG report and government cert. | 0.632 | 4 |
| Total average | 0.418 | 27 |

### *4.2. Regression analysis*

The second-stage analysis was conducted to clarify the effects of different types of GLPs on the financial efficiency of Korean logistics companies. The first model aimed to identify the overall effect of GLPs, without considering elements of GLPs. In Model 1-1, the size of the companies was included as a control variable, represented by the natural logarithm of their sales. In Model 1–2, the independent variable of GLPs was added, while the dependent variable was the DEA-SBM score. Table 6 presents the coefficient estimates of β from the two Tobit regression models. In Model 1-1, the size of the logistics companies (LN of sales) was positively associated with their financial efficiency ($\beta = 0.04$, $P < 0.1$). In Model 1–2, conducting GLPs was not found to have a positive effect on the financial efficiency of Korean logistics companies ($\beta = -0.20$, $P < 0.01$).

While the traditional perspective that environmental regulations represent an extra financial burden for the company, diminishing profitability and resulting in reduced efficiency, some previous studies revealed that better environmental performance from GLPs could lead to improved financial performance [56,57]. Our finding seemed in line with the traditional perspective. However, it remained that categorized GLPs could act differently on financial performance. So the second model was proposed for further detailed analysis of the relationship between GLPs and financial performance.

The second model examined elements of GLPs as independent variables. DEA-SBM score was the dependent variable, and the control variable was the sales of each company, converted to a natural logarithm. Table 7 presents the coefficient estimates of β from the two Tobit regression models. In model 2-1, the size (LN of sales) of logistics companies was positively related to their financial efficiency ($\beta = 0.04$, $P < 0.1$). In model 2-2, GLPs without ESG reports and government certification ($\beta = -0.25$, $P < 0.01$), and ESG reports ($\beta = -0.32$, $P < 0.05$) were negatively associated with financial efficiency. A government green certification showed a negative association with efficiency, but it was not statistically significant. However, GLPs with both ESG reports and a government green certification had a significant positive effect on the efficiency ($\beta = 0.54$, $P < 0.01$). The synergistic effect was further validated through Tobit regression analysis.

There has been an issue that companies might engage in symbolic adherence to environmental policies without genuinely striving to achieve environmental objectives [58]. In this sense, the independent verification of GLPs shall be required for their effectiveness in financial performance [55]. Green certification by the government could act as an official assessment and guarantee for GLPs by logistics companies in the right way. GLPs with public reports without government certification could be regarded as limited assessed

**Table 6**
Tobit regression modeling result (1).

| | Model 1-1 | | | | Model 1-2 | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Coef. | SE | t-value | P>\|t\| | Coef. | SE | t-value | P>\|t\| |
| (Intercept) | −0.69 | 0.61 | −1.13 | 0.26 | −2.03 | 0.76 | −2.69 | 0.01 |
| Size | 0.04 | 0.02 | 1.86 | 0.07* | 0.09 | 0.03 | 3.31 | 0.00*** |
| GLPs | | | | | −0.20 | 0.07 | −2.89 | 0.00*** |

*p < 0.1, **p < 0.05, ***p < 0.01.

**Table 7**
Tobit regression modeling result (2).

| | Model 2-1 | | | | Model 2-2 | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Coef. | SE | t-value | P>\|t\| | Coef. | SE | t-value | P>\|t\| |
| (Intercept) | −0.69 | 0.61 | −1.13 | 0.26 | −0.94 | 0.83 | −1.13 | 0.26 |
| Size | 0.04 | 0.02 | 1.86 | 0.07* | 0.05 | 0.03 | 1.69 | 0.09* |
| GLPs Only | | | | | −0.25 | 0.08 | −3.05 | 0.00*** |
| Report | | | | | −0.32 | 0.16 | −2.02 | 0.05** |
| Gov. cert | | | | | −0.14 | 0.09 | −1.58 | 0.12 |
| Report & GC | | | | | 0.54 | 0.19 | 2.87 | 0.01*** |

*p < 0.1, **p < 0.05, ***p < 0.01.

and verified since the reports were voluntary actions without tight audits by the independent entities. The GLPs with the reports and government certification could be regarded as collaboratively assessed and verified with the private and public efforts. Consequently, GLPs can significantly enhance the financial efficiency of logistics companies when undertaken in conjunction with collaborative endeavors from both private and public sectors.

## 5. Conclusions

This study aimed to examine how GLPs influence the financial efficiency of logistics companies in the case of Korea. Additionally, it sought to understand the combined effects of GLPs and a pertinent government policy on the financial efficiency of these companies.

The GLPs can be sustained when they financially help logistics companies, which are private players seeking financial profit. GLPs of Korean logistics companies include various energy-saving practices such as optimizing their logistics business to reduce energy consumption, which could lead to cost reduction. Given the significant energy consumption in the logistics industry, it is essential to adopt environmentally friendly capabilities and implement various activities to reduce energy consumption [29,30]. Profitability in GLPs must be verified with the impact of a relevant government policy.

It was expected that GLPs would have a positive effect on financial efficiency. However, the way of implementing GLPs needed to be considered based on this research analysis. The results showed that public reports such as ESG reports, and a government green certification should be conducted together for GLPs of logistics companies to have a positive effect on their financial efficiency.

The public report has been a voluntary practice by companies, which means there has been no tight auditory obligation to it. The reports have been made public under the company names, so there has been little possibility of falsification, but it has still been possible for companies to modify inadequate or irrelevant actions to appear green. Therefore, government intervention or guarantees for GLPs of logistics companies, such as a green logistics certification, are required to supplement ESG reports and make them effective in improving financial efficiency. Similarly, a government policy alone, such as the certification for GLPs is not sufficient to improve the financial efficiency of logistics companies.

The virtuous circle of GLPs involves being profitable while contributing to the environment. The ideal cycle for logistics companies can be achieved with both the companies and the government complementing each other's efforts. The government needs to expand the benefits of GLPs for logistics companies to motivate more companies to adopt such practices. It is recommended that logistics companies' ESG reports should be mandatory and linked to government policies such as the green logistics certification to make them more reliable and effective. ESG reports are an excellent source for investors looking for companies contributing to sustainable environmental practices. Therefore, the report's reliability can be enhanced when supplemented by government policies, including the green logistics certification. The private and public sectors' efforts need to be synchronized to create a virtuous cycle that can make GLPs profitable.

The need for the conjunction of the public and private to achieve green growth and green economy has been stated in other studies [59,60]. Even though the previous studies have tended to be a wide range of green adoption rather than the specific industry, the result of our study is on the same line as the previous one. These findings underscore the importance of collaborative efforts between the private and public sectors, emphasizing that the profitability of greener practices is contingent on a harmonious partnership between government policies and corporate transparency initiatives through public reports.

In conclusion, GLPs including public reporting and a pertinent government policy can generate better financial efficiency. In other words, greener practices in the logistics industry can be adopted in more sustainable ways in the capitalistic society when a system can harmonize endeavors from private and public sectors. It is quite apparent that greening and profitability could be together when the private and public sectors are aligned in the sustainable system.

## 6. Limitations and suggestions

This study aimed to see if GLPs could improve the financial efficiency of logistics companies. The pooling way was adopted for the second stage analysis. Future research could be done in a time series way to see the effects of green practices and other elements on the financial efficiency of logistics companies. The need for close collaboration between the public and private sectors was proved in this study. Therefore, the subject of future research can include clarifying ways to strengthen the close collaboration of the government and private companies in logistics sectors to achieve financially sustainable GLPs.

## Data availability

The authors do not have the permission to share data.

## CRediT authorship contribution statement

**Dohyun Kim:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Joonho Na:** Software, Investigation, Data curation, Conceptualization. **Hun-Koo Ha:** Writing – review & editing, Supervision, Methodology, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## References

[1] Prado-Lorenzo, L. Rodríguez-Domínguez, I. Gallego-Álvarez, I.-M. García-Sánchez, Factors influencing the disclosure of greenhouse gas emissions in companies world-wide, Manag. Decis. 47 (7) (2009) 1133–1157, https://doi.org/10.1108/0025174091097834.
[2] Centobelli, R. Cerchione, E. Esposito, Environmental sustainability in the service industry of transportation and logistics service providers: Systematic literature review and research directions, Transport. Res. Transport Environ. 53 (2017) 454–470, https://doi.org/10.1016/j.trd.2017.04.032.
[3] P. Evangelista, Environmental sustainability practices in the transport and logistics service industry: an exploratory case study investigation, Research in Transportation Business & Management 12 (2014) 63–72, https://doi.org/10.1016/j.rtbm.2014.10.002.
[4] Govindan, M. Kilic, A. Uyar, A.S. Karaman, Drivers and value-relevance of CSR performance in the logistics sector: a cross-country firm-level investigation, Int. J. Prod. Econ. 231 (2021) 107835, https://doi.org/10.1016/j.ijpe.2020.107835.
[5] Pieters, H. Glöckner, S.W. Omta, S. Weijers, Dutch logistics service providers and sustainable physical Distribution: searching for focus, Int. Food Agribus. Manag. Rev. 15 (B) (2012) 107–126.
[6] Maas, T. Schuster, E. Hartmann, Pollution prevention and service stewardship strategies in the third-party logistics industry: effects on firm differentiation and the moderating role of environmental communication, Bus. Strat. Environ. 23 (1) (2014) 38–55, https://doi.org/10.1002/bse.1759.
[7] Oberhofer, E. Fürst, Sustainable development in the transport sector: influencing environmental behaviour and performance, Bus. Strat. Environ. 22 (6) (2013) 374–389, https://doi.org/10.1002/bse.1750.
[8] Lieb, R.C. Lieb, Environmental sustainability in the third-party logistics (3PL) industry, Int. J. Phys. Distrib. Logist. Manag. 40 (7) (2010) 524–533, https://doi.org/10.1108/09600031011071984.
[9] Abbasi, F. Nilsson, Developing environmentally sustainable logistics; Exploring themes and challenges from a logistics service providers' perspective, Transport. Res. Transport Environ. 46 (2016) 273–283, https://doi.org/10.1016/j.trd.2016.04.004.
[10] W. Zhang, M. Zhang, W. Zhang, Q. Zhou, X. Zhang, What influences the effectiveness of green logistics policies? A grounded theory analysis, Sci. Total Environ. 714 (2020) 136731, https://doi.org/10.1016/j.scitotenv.2020.136731, 136731.
[11] Laari, J. Töyli, L. Ojala, The effect of a competitive strategy and green supply chain management on the financial and environmental performance of logistics service providers, Bus. Strat. Environ. 27 (7) (2018) 872–883, https://doi.org/10.1002/bse.2038.
[12] Wolf, Improving the sustainable development of firms: the role of employees, Bus. Strat. Environ. 22 (2) (2013) 92–108, https://doi.org/10.1002/bse.1731.
[13] Lun Venus, K. Lai, C.W.Y. Wong, T.C.E. Cheng, Greening propensity and performance implications for logistics service providers, Transport. Res. E Logist. Transport. Rev. 74 (2015) 50–62, https://doi.org/10.1016/j.tre.2014.10.002.
[14] Baz, I. Laguir, Third-party logistics providers (TPLs) and environmental sustainability practices in developing countries: the case of Morocco, Int. J. Oper. Prod. Manag. 37 (10) (2017) 1451–1474, https://doi.org/10.1108/IJOPM-07-2015-0405.
[15] Oberhofer, M. Dieplinger, Sustainability in the transport and logistics sector: lacking environmental measures, Bus. Strat. Environ. 23 (4) (2014) 236–253, https://doi.org/10.1002/bse.1769.
[16] Piecyk, M. Björklund, Logistics service providers and corporate social responsibility: sustainability reporting in the logistics industry, Int. J. Phys. Distrib. Logist. Manag. 45 (5) (2015) 459–485, https://doi.org/10.1108/IJPDLM-08-2013-0228.
[17] Hart, A natural-resource-based view of the firm, Acad. Manag. Rev. 20 (4) (1995) 986–1014, https://doi.org/10.2307/258963.
[18] Markley, L. Davis, Exploring future competitive advantage through sustainable supply chains, Int. J. Phys. Distrib. Logist. Manag. 37 (9) (2007) 763–774, https://doi.org/10.1108/09600030710840859.
[19] Porter, C. Linde, van der, Toward a new conception of the environment-competitiveness relationship, J. Econ. Perspect. 9 (4) (1995) 97–118, https://doi.org/10.1257/jep.9.4.97.
[20] Carmona-Moreno, J. Céspedes-Lorente, J. De Burgos-Jiménez, Environmental strategies in Spanish hotels: contextual factors and performance, Serv. Ind. J. 24 (3) (2004) 101–130, https://doi.org/10.1080/0264206042000247786.
[21] Foster, S.E. Sampson, S.C. Dunn, The impact of customer contact on environmental initiatives for service firms, Int. J. Oper. Prod. Manag. 20 (2) (2000) 187–203, https://doi.org/10.1108/01443570010304251.
[22] Davarzani, B. Fahimnia, M. Bell, J. Sarkis, Greening ports and maritime logistics: a review, Transport. Res. Transport Environ. 48 (2016) 473–487, https://doi.org/10.1016/j.trd.2015.07.007.
[23] Froio, B.S. Bezerra, Environmental sustainability initiatives adopted by logistics service providers in a developing country – an overview in the Brazilian context, J. Clean. Prod. 304 (2021) 126989, https://doi.org/10.1016/j.jclepro.2021.126989.
[24] Lin, Y.-H. Ho, Determinants of green practice adoption for logistics companies in China, J. Bus. Ethics 98 (1) (2011) 67–83, https://doi.org/10.1007/s10551-010-0535-9.
[25] Perotti, M. Zorzini, E. Cagno, G.J.L. Micheli, Green supply chain practices and company performance: the case of 3PLs in Italy, Int. J. Phys. Distrib. Logist. Manag. 42 (7) (2012) 640–672, https://doi.org/10.1108/09600031211258138.
[26] Colicchia, G. Marchet, M. Melacini, S. Perotti, Building environmental sustainability: empirical evidence from Logistics Service Providers, J. Clean. Prod. 59 (2013) 197–209, https://doi.org/10.1016/j.jclepro.2013.06.057.
[27] Wolf, S. Seuring, Environmental impacts as buying criteria for third party logistical services, Int. J. Phys. Distrib. Logist. Manag. 40 (1/2) (2010) 84–102, https://doi.org/10.1108/09600031011020377.

[28] Tacken, V. Sanchez Rodrigues, R. Mason, Examining CO2e reduction within the German logistics sector, Int. J. Logist. Manag. 25 (1) (2014) 54–84, https://doi.org/10.1108/IJLM-09-2011-0073.

[29] He, P. Chen, H. Liu, Z. Guo, Performance measurement system and strategies for developing low-carbon logistics: a case study in China, J. Clean. Prod. 156 (2017) 395–405, https://doi.org/10.1016/j.jclepro.2017.04.071.

[30] Karaman, M. Kilic, A. Uyar, Green logistics performance and sustainability reporting practices of the logistics sector: the moderating effect of corporate governance, J. Clean. Prod. 258 (2020) 120718, https://doi.org/10.1016/j.jclepro.2020.120718.

[31] M. Vienažindienė, V. Tamulienė, J. Zaleckienė, Green logistics practices seeking development of sustainability: evidence from Lithuanian transportation and logistics companies, Energies 14 (22) (2021) 7500, https://doi.org/10.3390/en14227500.

[32] L.B. Prataviera, A. Creazza, S. Perotti, A call to action: a stakeholder analysis of green logistics practices, Int. J. Logist. Manag. (2023), https://doi.org/10.1108/IJLM-09-2022-0381.

[33] P. Evangelista, C. Colicchia, A. Creazza, Is environmental sustainability a strategic priority for logistics service providers? J. Environ. Manag. 198 (2017) 353–362, https://doi.org/10.1016/j.jenvman.2017.04.096.

[34] G. Marchet, M. Melacini, S. Perotti, Environmental sustainability in logistics and freight transportation: a literature review and research agenda, J. Manuf. Technol. Manag. 25 (6) (2014) 775–811, https://doi.org/10.1108/JMTM-06-2012-0065.

[35] T.M. Huynh, G. Kim, H.-K. Ha, Comparative analysis of efficiency for major Southeast Asia airports: a two-stage approach, J. Air Transport. Manag. 89 (2020) 101898, https://doi.org/10.1016/j.jairtraman.2020.101898.

[36] B.T. Yen, M.J. Huang, H.J. Lai, H.H. Cho, Y.L. Huang, How smart port design influences port efficiency–a dea-tobit approach, Research in Transportation Business & Management 46 (2023) 100862, https://doi.org/10.1016/j.rtbm.2022.100862.

[37] D. Wu, H. Li, Q. Huang, C. Li, S. Liang, Measurement and determinants of smart destinations' sustainable performance: a two-stage analysis using DEA-Tobit model, Curr. Issues Tourism (2023) 1–17, https://doi.org/10.1080/13683500.2023.2228977.

[38] S. Shuai, Z. Fan, Modeling the role of environmental regulations in regional green economy efficiency of China: empirical evidence from super efficiency DEA-Tobit model, J. Environ. Manag. 261 (2020) 110227, https://doi.org/10.1016/j.jenvman.2020.110227.

[39] Charnes, W.W. Cooper, E. Rhodes, Measuring the efficiency of decision making units, Eur. J. Oper. Res. 2 (6) (1978) 429–444, https://doi.org/10.1016/0377-2217(78)90138-8.

[40] Banker, A. Charnes, W.W. Cooper, Some models for estimating technical and scale inefficiencies in data envelopment analysis, Manag. Sci. 30 (9) (1984) 1078–1092, https://doi.org/10.1287/mnsc.30.9.1078.

[41] Tone, A slacks-based measure of efficiency in data envelopment analysis, Eur. J. Oper. Res. 130 (3) (2001) 498–509, https://doi.org/10.1016/S0377-2217(99)00407-5.

[42] Tone, M. Tsutsui, Network DEA: a slacks-based measure approach, Eur. J. Oper. Res. 197 (1) (2009) 243–252, https://doi.org/10.1016/j.ejor.2008.05.027.

[43] Ü. Sağlam, A two-stage performance assessment of utility-scale wind farms in Texas using data envelopment analysis and Tobit models, J. Clean. Prod. 201 (2018) 580–598, https://doi.org/10.1016/j.jclepro.2018.08.034.

[44] CELC-Status of certified logistics companies in South Korea, List of Certified Logistics Companies, 2021. https://celc.koti.re.kr/new_sub5/currentInfoBoard/list.

[45] Wong, K.L. Soh, C.L. Chong, N. Karia, Logistics firms performance: efficiency and effectiveness perspectives, Int. J. Prod. Perform. Manag. 64 (5) (2015) 686–701, https://doi.org/10.1108/IJPPM-12-2013-0205.

[46] Min, S.-J. Joo, Benchmarking third-party logistics providers using data envelopment analysis: an update, Benchmark Int. J. 16 (5) (2009) 572–587, https://doi.org/10.1108/14635770910987814.

[47] Zhou, H. Min, C. Xu, Z. Cao, Evaluating the comparative efficiency of Chinese third-party logistics providers using data envelopment analysis, Int. J. Phys. Distrib. Logist. Manag. 38 (4) (2008) 262–279, https://doi.org/10.1108/09600030810875373.

[48] N. Donthu, E.K. Hershberger, T. Osmonbekov, Benchmarking marketing productivity using data envelopment analysis, J. Bus. Res. 58 (11) (2005) 1474–1482, https://doi.org/10.1016/j.jbusres.2004.05.007.

[49] C. Serrano-Cinca, Y. Fuertes-Callén, C. Mar-Molinero, Measuring DEA efficiency in Internet companies, Decis. Support Syst. 38 (4) (2005) 557–573, https://doi.org/10.1016/j.dss.2003.08.004.

[50] S. Laari, J. Töyli, L. Ojala, The effect of a competitive strategy and green supply chain management on the financial and environmental performance of logistics service providers, Bus. Strat. Environ. 27 (7) (2018) 872–883, https://doi.org/10.1002/bse.2038.

[51] A. Gotschol, P. De Giovanni, V.E. Vinzi, Is environmental management an economically sustainable business? J. Environ. Manag. 144 (2014) 73–82, https://doi.org/10.1016/j.jenvman.2014.05.001.

[52] N. Hrovatin, N. Dol?sak, J. Zori?c, Factors impacting investments in energy efficiency and clean technologies: empirical evidence from Slovenian manufacturing firms, J. Clean. Prod. 127 (2016) 475–486, https://doi.org/10.1016/j.jclepro.2016.04.039.

[53] C.R. Carter, D.S. Rogers, A framework of sustainable supply chain management: moving toward new theory, Int. J. Phys. Distrib. Logist. Manag. 38 (5) (2008) 360–387, https://doi.org/10.1108/09600030810882816.

[54] S. Perotti, L.B. Prataviera, M. Melacini, Assessing the environmental impact of logistics sites through CO2eq footprint computation, Bus. Strat. Environ. 31 (4) (2022) 1679–1694, https://doi.org/10.1002/bse.2976.

[55] J. Xie, W. Nozawa, M. Yagi, H. Fujii, S. Managi, Do environmental, social, and governance activities improve corporate financial performance? Bus. Strat. Environ. 28 (2) (2019) 286–300.

[56] C. Fang, J. Zhang, Performance of green supply chain management: a systematic review and meta analysis, J. Clean. Prod. 183 (2018) 1064–1081, https://doi.org/10.1016/j.jclepro.2018.02.171.

[57] I. Laguir, R. Stekelorum, J. El Baz, Going green? Investigating the relationships between proactive environmental strategy, GSCM practices and performances of third-party logistics providers (TPLs), Prod. Plann. Control 32 (13) (2021) 1049–1062.

[58] F. Haque, C.G. Ntim, Environmental policy, sustainable development, governance mechanisms and environmental performance, Bus. Strat. Environ. 27 (3) (2018) 415–435.

[59] R.H. Ansah, S. Sorooshian, Green economy: private sectors' response to climate change, Environ. Qual. Manag. 28 (3) (2019) 63–69, https://doi.org/10.1002/tqem.21620.

[60] N. Droste, B. Hansjürgens, P. Kuikman, N. Otter, R. Antikainen, P. Leskinen, M. Thomsen, Steering innovations towards a green economy: understanding government intervention, J. Clean. Prod. 135 (2016) 426–434, https://doi.org/10.1016/j.jclepro.2016.06.123.