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Fujian's Industrial Eco-Efficiency: Evaluation Based on SBM and the Empirical Analysis of Influencing Factors

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Abstract: The coordinated development of industrialization and its ecological environment are vital antecedents to sustainable development in China. However, along with the accelerating development of industrialization in China, the contradiction between industrial development and environment preservation has turned out to be increasingly evident and inevitable. Eco-efficiency can be seen either as an indicator of environmental performance, or as a business strategy for sustainable development. Hence, industrial eco-efficiency promotion is the key factor for green industrial development. This study selects indicators relevant to resources, economy, and the environment of industrial development, and the indicators can well reflect the characteristics of industrial eco-efficiency. The SBM (Slacks-Based Measure) model overcomes the limitations of a radial model and directly accounts for input and output slacks in the efficiency measurements, with the advantage of capturing the entire aspect of inefficiency. This study evaluates the industrial eco-efficiency of nine cities in Fujian province during the period of 2006–2016, based on undesired output SBM (Slacks-Based Measure) model and also uses a Tobit regression model to analyze the influencing factors. The results show that there is a positive correlation among the economic development level, opening level, research and development (R&D) innovation, and industrial eco-efficiency in Fujian Province. However, a negative correlation was found between the industrial structure and industrial eco-efficiency in Fujian Province. Moreover, environmental regulation in Fujian Province was not found to significantly influence the industrial eco-efficiency. Hence, through the systematic analysis of industrial eco-efficiency and its influencing factors in Fujian, the study gives further insight on how policy-making can help achieve sustainable development, balancing between economic benefits and ecological improvements.

Keywords: industrial eco-efficiency; SBM model; Tobit regression model; industrial development; Fujian province

1. Introduction

Since the reforms and opening-up process in the late 1970s, China's rapid-developed industry has relied excessively on the resources inputs [1]. Meanwhile, Chinese industrial units were developing as huge pollutant emitters [2]. According to the "BP World Energy Statistical Yearbook 2016", China's total energy consumption accounted for 23% of the world's total energy consumption in 2015 resulting in a total of 27% of the world's carbon dioxide emissions [3]. Hence, in this highly turbulent situation, some serious concerns are raised to keep production sustainable in the long run [4]. The green development has become an inevitable choice for industrial development across different countries of the world [5]. Since industrial development plays a critical role in the economic growth of China [6], the industrial sector urgently needs changes in its structural optimization and power conversion to promote green transformation for coordinated development between economic growth and ecological environment.

Fujian is one of the first ecological civilization demonstration areas, which has put ecological awareness for its industrial development in a prominent position for years. Hence, the industrial development in Fujian Province has rapidly evolved since the reforms and opening-up process, resulting in an unprecedented increase in the provincial industrial outputs [7]. Nevertheless, the problem of industrial pollution is still undeniable which has constrained the sustainable development of Fujian's industrial economy. Chinese President Xi Jinping raised the initiative of jointly building the Silk Road Economic Belt and the 21st-Century Maritime Silk Road (the Belt and Road) which have both attracted attention from all over the world. Accelerating the building of the Belt and Road can help promote the economic prosperity of the regions along the Belt and Road, which will additionally provide an excellent opportunity for the industrial development in the Southeast region of China. Therefore, seizing up development opportunities, upgrading industry and coordinating industrial development and environmental development, have all become Fujian's top priority.

Eco-efficiency is noted as an evaluation of the relationship between human production activities and regional ecological capacity which expected to use the least possible resources input and its resultant pollution emissions to create the highest possible economic benefits [8]. According to the theory of Moutinho et al. [9], most of the analyzed cities seem to have suboptimal scales, being one of the causes of their inefficiency. Zhang et al. [1] use three-stage data envelopment analysis and show that China's national average industrial eco-efficiency has declined by 30%. At present, Fujian Province has the historical mission of promoting the construction of the first national ecological demonstration zone, adhering to the green cycle and low carbon development, as well as saving energy and reducing pollution emissions [7]. Hence, the present study attempts to highlight an effective way to resolve the conflict between industrial development and its environment in Fujian Province. The current level of coordinated development between industry and its environment may be better conceptualized by evaluation of eco-efficiency, and then propose solutions to existing problems. Moreover, this may provide a holistic direction for promoting a harmonious coexistence between the industry and its environment. Hence, through the evaluation and analysis of the industrial eco-efficiency of Fujian Province and its influencing factors, the present study sheds light on how to effectively improve the level of industrial eco-efficiency in Fujian. This research will not only attempt to accumulate the research experience of eco-efficiency evaluation, but also help to enrich the theory of green development in its empirical analysis.

The rest of the paper is organized as follows: Section 2 provides a literature review of related concepts and models; Section 3 attempts to construct the model and index to evaluate the industrial eco-efficiency in Fujian province; Section 4 presents an analysis of the influencing factors of industrial eco-efficiency in Fujian province; Section 5 provides conclusions and policy implications; and Section 6 presents conclusions and limitations.

2. Literature Review

The concept of eco-efficiency was first proposed by two German scholars, Schaltegger and Sturm in 1990 [10], yet it was not widely responded to until 1992, when the WBCSD (World Business Council for Sustainable Development) defined eco-efficiency. It demands that the products and services should control resource consumption and environmental pollution as well as achieve the harmonious development of economy and ecology on the premise of satisfying the demand of human beings [11]. This definition further explores the relationship among the economy, society, and the environment which has proved its validity and attracted an increasing number of scholars. Since then, eco-efficiency has attracted more attention. From this perspective, some international organizations have started to study the concept and connotation of eco-efficiency and have presented numerous theoretical foundations, for example, resource and environmental issues and the harmony between human and natural environment [12]. Moving forward in this stream of development, the definition of eco-efficiency given by the OECD (The Organization for Economic Cooperation and Development) stands prominently among its cohorts. The OECD believes that the WBCSD's definition of eco-efficiency is more flexible and results-oriented, which can promote the practical actions of all the sectors of society to improve eco-efficiency [13]. However, this definition does not suggest the in-depth analysis of factors that may affect economic development and environmental quality issues as well as the psychological activities and behavioral motives of the participants. Therefore, OECD defines eco-efficiency as meeting the human needs with the viewpoint of utilization of ecological resources. It is measured as the ration between the (added) value of what has been produced (e.g., profits) and the added environment impacts of products or services (e.g., pollutant emissions) [14]. Furthermore, many scholars across different fields have studied the concept of eco-efficiency. For example, Meier [15] believes that eco-efficiency is the result of an interaction between economic and environmental benefits in tandem with environmental governance cost. Moreover, Desimone [16], Hellweg [17], and Lehni et al. [18] propose the evaluation index system, which has a certain reference value for the multifarious research of eco-efficiency in different fields.

Most of the studies presenting the concept and connotation of eco-efficiency are based on the definitions proposed by international scholars. Chinese scholars are newer to the field of eco-efficiency; nevertheless, their contribution to research still exists and is acknowledged. For example, Wang [19] notes that eco-efficiency is a ratio between the value created by a unit product, resources which are consumed as well as resulting pollution emissions. The scholar additionally proposes that improvements in the management of technology can effectively improve resource utilization [19]. Chu [20] believes that eco-efficiency is also called resource productivity, which can be understood in terms of the ratio between gross domestic product (GDP) and resource consumption as well as environmental pollution. Additionally, it is considered as an important indicator reflecting the green competitiveness of a country or region as well [20]. Qiu [21] documents that the concept of eco-efficiency cannot be generalized, and it needs to be redefined by a comprehensive understanding of the input and output according to the specific economic activities of the study subject. In addition, many scholars have conducted extensive research on the concept of eco-efficiency. Li [22] notes that eco-efficiency is a revolutionary environmental-management method which sums up different values to be achieved, development processes, the improvement of ecological efficiency, and the promotion path. Mao et al. [23] describe the concept of eco-efficiency as one of the indicators of environmental management performance to measure the relationship between environmental load and economic development. It is found that some scholars use the concept of eco-efficiency to promote the development of the circular economy as well. From this perspective, to promote the development of the circular economy in China, Dai et al. [24] integrate the concept of eco-efficiency into the measures for the development of circular economy proposing an eco-efficiency system to evaluate the development of the circular economy in China. Hence, the mentioned research on the concept of eco-efficiency shows that there is no unified definition of eco-efficiency. Although the core concept of ecological efficiency has been recognized and maintained by most of the scholars, different concepts, research areas, and research levels often offer different meanings and connotations of eco-efficiency. Hence, the mentioned theoretical underpinnings assert a need to develop appropriate research grounds to deeply study the relationship between economic output, resource consumption, and environmental impact within the diversified industrial realms and explore the paths of harmonious development of the economy and ecology.

The DEA (Data Envelopment Analysis) model, initially presented by Charnes et al. [25], has some advantages. Since it derives sole relative efficiency, the DEA model is suitable to be adopted in a complex industrial environment [26]. Furthermore, the DEA model provides an easier and more flexible means of estimation because the knowledge of the functional relationship between inputs and outputs is not required, and weights to inputs and outputs do not have to be assigned [27]. Due to these advantages, many scholars have tried to use the DEA Model to evaluate the industrial eco-efficiency [1]. Korhonen [28] used two extended DEA methods in order to evaluate the eco-efficiency of twenty-four power plants in Europe. Sarkis [29] attempted to incorporate six DEA models to evaluate the ecological efficiency of power plants. More precisely, Yang [30], Wang et al. [31], and Wang [32] used the DEA model in order to evaluate the industrial eco-efficiency of China's 31 provinces and cities. These studies have focused on analyzing the development of China's industrial eco-efficiency in tandem with highlighting the differences and evolutionary trends of industrial eco-efficiency between provinces, as well as the relationship between industrial eco-efficiency and the economic development level of research objects. Some scholars particularly document the research findings of industrial eco-efficiency within the context of some specific provinces. For example, Zhang et al. [33], Liu et al. [34] endeavored to measure the industrial eco-efficiency of Anhui Province and Hunan Province based on the DEA model. In order to better understand and examine the concepts of industrial eco-efficiency and regional differences, some scholars further enriched the research notions of the traditional DEA model and focused more on the super-efficiency DEA model [35,36]. Yang et al. [37], Zhang et al. [38] used the network DEA model to evaluate the eco-efficiency of 30 provinces in China and the Yangtze River City Cluster. Hence, the theoretical underpinnings noted by different scholars show that the DEA model can be used to evaluate the eco-efficiency of the input-output indicators and may help to neutralize the consequences of a single-ratio method that cannot measure multiple indicators at the same time. The DEA has its vivid analytical approach that is not normally affected by factors such as the differences in the unit measurement of indicator data and the subjective weight of indicators. Moreover, this analytical method helps to propose the direction and route of improvement at the same time for non-effective decision-making units. The DEA model, therefore, has gradually become the mainstream method for evaluating industrial eco-efficiency in recent years.

2.1. Research Hypotheses

The level of industrial eco-efficiency is different in the different cities of Fujian Province. According to observed reality and previous literature, multiple factors affect industrial eco-efficiency including the level of economic development [34,36], the level of opening to the outside world [39], industrial structure [34,36,40], research and development (R&D) and innovation [31,36], and environmental regulations [31,41].

2.1.1. Economic Development and Industrial Eco-Efficiency

The level of economic development is considered as a comprehensive manifestation of the economic scale and growth rate of a region that has the impacts on the consumption of resources and environment. It is found that, with the development of the economy, the level of per capita income has been raised, and people have begun to pursue a higher quality living environment [42]. This willingness encourages people to make environmentally friendly choices when they consume products. From this perspective, it is documented that industrial enterprises are attempting to initiate a green production process to meet the market demands for eco-friendly products. People's ecological demands have positive guidance and promotion roles for the industrial development which is not only conducive to the improvement of environmental quality but also conducive to the improvement of industrial ecological efficiency [38]. Therefore, the following hypothesis is developed:

Hypothesis 1 (H1). *The higher level of economic development may lead to the higher level of industrial eco-efficiency.*

2.1.2. Industrial Structure and Industrial Eco-Efficiency

Industrial eco-efficiency has significant differences according to industrial growth scale and rate, energy and resource consumption, and pollutant emissions. The regional industrial structure has a direct impact on industrial pollution [43]. The region's environmental quality is reflected by its industrial structure [1]. Changes in the industrial structure may cause corresponding changes in the quality of the environment. As it will result in changes in energy demand, the intensity of consumption, and consumption structure as well as have different effects on economic development and the environment. Ma et al. [44] note that the differences in industrial structure have important impacts on the coordination of economy and environment. It is further documented that the regional industrial structure with low coordination between the economy and the environment tends to be dominated by some industries such as petrochemical, coal, power generation, and iron and steel. This industrial structure focuses on the high degree of coordination between the economy and the environment in high-end equipment manufacturing industries such as electronic machinery and intelligent manufacturing. From this perspective, it is ascertained that the industrial characteristics of heavy industry may have a high consumption of resources and high pollution which has a significant inhibitory effect on industrial eco-efficiency. Especially during a period in which the heavy industry is highly active, significantly high energy consumption and pollution emission levels are present and cause serious disturbances to the environment [43]. Empirical studies also show that the higher the proportion of local heavy industry output value, the more serious the environmental pollution that may undermine its industrial eco-efficiency [45]. The gross industrial output value of light industry in Fujian province was 22,255 trillion yuan in 2016, whereas that of heavy industry was 22,289 trillion yuan. Industrial added value rate of light industry in Fujian province was 25.55% in 2016, and that of heavy industry was 22.61%. In addition, the general theory holds that in three major industries, the industry including products consumes the largest amount of resources and energy. It is asserted that this difference in industry structure may inevitably affect the level of industrial eco-efficiency [46]. Therefore, the following hypothesis is proposed:

Hypothesis 2 (H2). *The smaller proportion of heavy industry in the industrial structure may bring a higher level of industrial ecological efficiency.*

2.1.3. Innovation R&D and Industrial Eco-Efficiency

Innovation is an important driving force for sustained economic growth and is the key to maintaining the core competitiveness of the industry [47]. R&D innovation mainly affects industrial eco-efficiency in two aspects: On the one hand, the improvement of production technology can effectively reduce the input of raw materials and energy consumption of unit products in tandem with increasing production efficiency. At the same time, the R&D of new energy, green manufacturing, and new materials may effectively promote the development of emerging industries and become a new driving force for the transformation, upgrading, and sustainable development of the industrial structures. On the other hand, innovation R&D plays a crucial role in improving environmental performance [48]. Technological innovation may promote the development of technologies such as energy conservation and emission reduction, clean energy, and pollution treatment [36]. It will not only create conditions for companies to achieve cleaner production, but also reduce waste emissions and energy consumption, as well as ease resource constraints and environmental pressures in tandem with improving environmental quality. The discussed theoretical underpinnings develop ground to postulate that:

Hypothesis 3 (H3). *The stronger the R&D and innovation capabilities, the higher the industrial eco-efficiency.*

2.1.4. Opening to the Outside World and Industrial Eco-Efficiency

The level of opening to the outside world has provided sufficient financial support for the development of economy through investment promotion. At the same time, it has also incorporated advanced production technology and management experience that may help in promoting the development of the country's economy [39]. Considering the example of China, it is noted that after the reform and opening-up process, especially since the 1990s, the proportion of China's actual industrial use of foreign direct investment (FDI) has increased dramatically [49]. Moreover, the total amount of industrial foreign trade exports has also experienced continuous growth. Hence, the Chinese industries have achieved a leap-forward development stage where FDI has gained momentum for promoting China's industrialization. However, except for adequate capital and technical support from foreign investment stakeholders, the issue of environmental pollution caused by foreign-funded enterprises has attracted widespread attention [50]. The trade between countries creates conditions for the different environmental needs of countries with different income. It is noted that high-income countries consume the products sacrificing environment of low-income countries [51]. Although "pollution transfer" occurs during the introduction of FDI, the advanced technology and management experience in the transfer process is also conducive to the improvement of the host country's environmental quality [52]. Therefore, the following hypothesis is stated:

Hypothesis 4 (H4). *The higher the level of opening to the outside world, the higher the industrial eco-efficiency.*

2.1.5. Environmental Regulation and Industrial Eco-Efficiency

Proper environmental regulations contribute to improving resource efficiency as well as enterprises' technological innovation and thus becoming a positive driving force of overall industry and economy development [53]. Based on an OECD study [54], environmental policies are critical ways of promoting green development. From the perspective of controlling and preventing environmental pollution and protecting the environment, environmental regulation is a policy that restricts economic activities by series instruments including legal regulations, planning programs, and response measures as well as market guidance, social efforts, and other management methods [55]. Some scholars suggested providing guidance and incentives for the green transform of enterprises by fund investment and financial aid [56]. Hence, environmental regulation is regarded as the external regulatory process that helps to control the behavior of the industrial subject. Additionally, environmental regulation can be kept as an external regulatory power. It provides support in regulating the behavior of the industrial subject in both positive and negative directions in tandem with having an important influence on the improvement of environmental quality [57]. From this perspective, the following hypothesis attempts to propose that:

Hypothesis 5 (H5). *The more perfect the environmental regulation, the higher the industrial eco-efficiency.*

In the past 20 years, there have been some models and methods for scholars to assess eco-efficiency, such as the ratio approach [58], the grey relational analysis method [59], the analytic hierarchy process method (AHP) [60], entropy weight method [61], data envelopment analysis (DEA) [28,47,62–65] and so on. Eco-efficiency was firstly used by simple ratio indicators such as inputs to outputs. However, these simple ratios were easily influenced by personal opinions [66]. Existing studies widely apply the DEA approach to evaluate industrial eco-efficiency [67,68]. DEA is an effective non-parametric approach for assessing the relative efficiency of a number of homogeneous decision-making units (DMUs) [69]. From this perspective, it is further found that there are many methods of measurement for DEA. For example, radial measurement method [28,47,64,70,71], non-radial measurement method [72,73], and directional distance function measurement method [74–81] to evaluate the efficiency. However, the impacts of the slacks were not taken into account for efficiency assessment while using these DEA methods. Since the slack is a critical factor of the inefficiency [66], Tone [82] proposed a slacks-based measure (SBM) of efficiency in 2001. SBM is a nonlinear fractional programming problem and the efficiency value of SBM was interpreted as the product of output and input inefficiencies. The present study endeavors to put forward those measurement methods that encapsulate all the slacks of input and undesirable outputs into its scope for eco-efficiency. Hence, the present study uses the SBM model of undesirable outputs to comprehensively evaluate the industrial eco-efficiency of Fujian Province.

3. Methodology

We apply SBM model to evaluate the industrial eco-efficiency, which directly takes into account the input and output slacks in the efficiency measurements, with the advantage of capturing the entire aspect of inefficiency. In the Energy and Environment (E and E) field, many scholars adopted the SBM model to evaluate efficiencies with undesirable output [83–85]. Additionally, SBM model always assumes the non-radial approach overcoming the limitations of a radial model. The present study, hence, uses the undesirable outputs SBM model to comprehensively evaluate the industrial eco-efficiency of Fujian Province from 2006 to 2016. This research attempts to command its scope from the perspective of resource and environmental input and output to examine the impact of eco-efficiency on Fujian's industry. The present study encapsulates main ecological factors into its scope in tandem with the construction of Tobit regression model, and systematic analysis of relevant factors affecting the industrial eco-efficiency of Fujian Province in order to provide a useful toolkit for enriching and developing the theory of industrial ecology. Additionally, this study may be helpful in upgrading and promoting continuous optimization of China's industrial structure.

3.1. Index System Construction

There are a growing number of scholars presenting industrial eco-efficiency research comprising of both input and output indicators. For example, Liu et al. [34] note industrial electricity consumption, water consumption, and industrial waste emissions as input variables in the measurement of industrial eco-efficiency, while considering total industrial output values as output variables. Guo et al. [36] document their research findings on the industrial eco-efficiency of China's six central provinces by considering industrial wastewater, waste gas, and industrial energy consumption as input indicators and industrial added value as the output value. Nevertheless, industrial emissions are treated as an undesirable output in research, because it is inconsistent with the actual conditions of industrial production, which may cause deviations in the measured results. From this perspective, Yang [86] documents research findings for Hunan Province by taking environmental pollution indicators (industrial wastes) as undesirable outputs and industrial output values as desirable inputs in tandem with industrial energy and water consumption as input indicators in the evaluation process of provincial industrial eco-efficiency.

Hence, input and output indicators that can well reflect the eco-efficiency are selected from the basic economic and industrial resources consumption and environmental indicators according to the characteristics and connotation of eco-efficiency. Meanwhile, the principles of operability and availability are also considered for indicator selection. Energy consumption and water consumption are used as resource consumption indicators. Industrial wastewater and industrial waste gases are selected as undesirable outputs in the index. Additionally, the regional industrial value added is considered as the desired output. An index system for evaluating the industrial eco-efficiency of Fujian Province is shown in Table 1.

Table 1. Industrial Eco-efficiency Evaluation Index System.

Category	Indicators	Specific Indicator	Description
Input	Resource consumption	Energy consumption (EC)	The amount of standard coals consumed by the province or municipality [87]
		Water consumption	Fresh water consumption [4]
Output	Desirable outputs	Industrial economic development	Industrial value added [4]
	Undesirable outputs	Industrial wastewater (IWW)	Total volume of wastewater discharge in industry [88]
		Industrial waste gases (IWG)	Total amount of industrial waste gas emission [88]

3.2. Model Construction

There are I DMUs, denoted by DMUi ($i = 1, 2, \ldots, I$). During the process, each DMUi ($i = 1, 2, \ldots, I$) transforms inputs x_i ($i = 1, 2, \ldots, I$) into desirable output y_i^g ($i = 1, 2, \ldots, I$) and undesirable outputs y_i^b ($i = 1, 2, \ldots, I$).

The input vector set is: $X = [x_1, x_2, \ldots, x_I] \in R^+_{m \times I}$

The desirable output vector set is expressed as: $Y^g = [y_1{}^g, y_2{}^g, \ldots, y_I{}^g] \in R^+_{Z1 \times I}$

The undesirable output vector set is denoted as: $Y^b = \left[y_1{}^b, y_2{}^b, \ldots, y_I{}^b\right] \in R^+_{Z2 \times I}$

We use undesirable outputs for conventional inputs [28,47,62,63]. Let $\lambda \geq 0$ be the intensity variables, so the production technology models under environmental constraints can be expressed as:

$$P = \left\{ \left(x, y^g, y^b\right) \middle| x \geq \lambda X, y^g \leq \lambda Y^g, y^b \geq \lambda Y^b, \sum_{i=1}^{I} \lambda = 1, \lambda \geq 0 \right\} \quad (1)$$

The SBM model for measuring the efficiency of a particular decision unit $DMU_0(x_0, y^g{}_0, y^b{}_0)$ is mentioned under the condition that it contains undesirable output and is constructed as:

$$\rho = \min \frac{1 - \frac{1}{m} \sum\limits_{i=I}^{m} \frac{s_j^-}{x_{j0}}}{1 + \frac{1}{z_1 + z_2} \left(\sum\limits_{r=1}^{z_1} \frac{s_r^{+g}}{y_{r0}^g} + \sum\limits_{r=1}^{z_2} \frac{s_r^{+g}}{y_{r0}^g} \right)}$$
$$s.t. \begin{cases} x_0 = \lambda X + s^- \\ y_0^g = \lambda Y^g - s^{+g} \\ y_0^b = \lambda Y^b + s^{+b} \\ \sum\limits_{i=1}^{I} \lambda = 1 \\ s^- \geq 0; s^{+g} \geq 0; s^{+b} \geq 0; \lambda \geq 0 \end{cases} \quad (2)$$

Equation (2) is based on the SBM model under VRS (variable return to scale), s^- is the input slack variable, s^{+g} is the slack variable of the expected output, s^{+b} is the slack variable of the undesired output, λ is the weight vector, $\rho*$ represents numerator and denominator respectively representing the input and the average expansion rate of output relative to production frontier as well as the average reduction ratio, i.e., output inefficiency and input inefficiency. The objective function $\rho*$ is about s^-, s^{+g}, s^{+b} strictly decreasing and is between 0 and 1. For a specific DMU (decision-making unit), the technology is valid only when both s^{+g*} and s^{+b*} are valid. $\rho* < 1$ indicates that the DMU is ineffective and can effectively be improved by the means of eliminating output and input slacks.

3.3. Data Sources

The data used in this study were derived from the statistical systems of China. Specifically, all the data were collected from Fujian Statistical Yearbook, China City Statistical Yearbook, Statistical Yearbook of nine cities in Fujian as well as the Statistical Communique on National Economy and Social Development. The industrial value added comes from Statistical Yearbook of various cities in Fujian each year. Energy consumption comes from Fujian Statistical Yearbook each year. Water consumption, industrial waste water and industrial waste gas come from China City Statistical Yearbook as well as the Statistical Yearbook, Statistical Communique on National Economy and Social Development of nine cities in Fujian each year. It was found that energy consumption is not directly counted in the statistical yearbook. Therefore, these data were got by conversion from energy consumption index and industrial value added. This study estimated industrial waste gas in Nanping and Longyan from 2006–2008 by interpolation because of a lack of data. The basic data statistics for analysis are shown in Table 2.

Table 2. Descriptive statistics.

Statistics	Energy Consumption (Tons of Standard Coal)	Water Consumption (1000 Cubic Meters)	Industrial Waste Water (10,000 Tons)	Industrial Waste Gases (10,000 Tons)	Industrial Value Added (10,000 Yuan)
Max	21,227,465	269,900	86,621.76	3806.79	32,121,845.65
Min	1,361,034	14,900	1303.19	121.71	1,199,699.70
Mean	7,623,431.82	83,220.2	13,333.7084	1498.6183	8,128,423.709
SD	5,457,983.544	54,838.1	16,838.93523	997.02809	6,892,788.949

3.4. Variable Selection

Based on the foregoing assumptions, the present study considers industrial eco-efficiency as the dependent variable, and factors that affect this value are considered as independent variables in order to analyze the industrial eco-efficiency of different cities in Fujian Province. The definitions of all variables and their associated explanations are shown in Table 3.

Table 3. Definitions and explanations of variables.

Variable	Variable Abbreviation	Definitions and Assigned Values
The level of economic development	RGDP UR	Per capita GDP (10,000 yuan/person) Urbanization rate (%)
Open to the outside world	FDI	Foreign direct investment as a percentage of GDP (%)
R&D and innovation	RDI	R&D expenditures of industrial enterprises as a percentage of industrial added value (%)
Industrial Structure	HEA	The proportion of gross industrial output to total industrial output (%)
Environmental Regulation	POL	Industrial pollution control investment proportion of industrial added value (%)

3.5. Regression Model

The present study incorporates Tobit regression analysis to find out the impact of influencing factors on eco-efficiency. The industrial eco-efficiency always has its value between 0 and 1. Therefore, using ordinary least squares (OLS) to estimate the regression coefficient has a problem in terms of the inconsistency of its regression coefficient and biased estimates. Hence, Tobit regression analysis is performed in order to measure the effects of different variables on industrial eco-efficiency by following the studies that used Tobit regression when the dependent variable was set as an efficiency score [89,90].

The basic form of the Tobit model is:

$$y_i = \begin{cases} 0,\ if\ {y_i}^* \leq 0 \\ {y_i}^*,\ if\ {y_i}^* > 0 \end{cases} \quad (3)$$

Combined with the research protocols of this study, the expression of the regression model of influencing factors is as follows:

$$\begin{aligned} y^*_{it} = \ & \beta_0 + \beta_1 Ln(RGDP_{it}) + \beta_2 UR_{it} + \beta_3 FDI_{it} \\ & +\beta_4 RDI_{it} + \beta_5 HEA_{it} + \beta_6 POL_{it} + \varepsilon_{it} \end{aligned} \quad (4)$$

In the formula: y^* indicates industrial eco-efficiency, RGDP indicates per capita GDP, UR indicates urbanization rate, FDI indicates the opening level to the outside world, RDI indicates R&D and innovation, HEA indicates industrial structure, POL indicates environmental regulation,

β_i is undetermined coefficient, and a random error term, and obey normal distribution. $i = 1, 2, 3, \ldots, N$, t indicates time ($t = 1, 2, \ldots, T$)

4. Results

4.1. Industrial Eco-Efficiency Values of Fujian Province

This study uses Max DEA PRO 6.0 software to measure the industrial eco-efficiency values of nine cities in Fujian Province from 2006 to 2016. The result are summarized in Table 4 and the visualized results are provided in Figures 1 and 2.

Table 4. Industrial Eco-efficiency of various cities in Fujian province.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
Fuzhou	0.9370	0.8145	0.8578	1.0000	0.9530	0.9751	1.0000	1.0000	1.0000	1.0000	1.0000	0.9579
Xiamen	1.0000	1.0000	1.0000	1.0000	1.0000	0.9038	1.0000	1.0000	1.0000	1.0000	1.0000	0.9913
Putian	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Sanming	0.2026	0.1931	0.1423	0.2047	0.1925	0.2276	0.1789	0.1887	0.1991	0.2263	0.3560	0.2102
Quanzhou	0.8943	0.8536	0.6357	0.6973	0.5926	0.7435	0.6518	0.7393	0.6949	0.5812	0.7969	0.7165
Zhangzhou	0.4411	0.4669	0.4533	0.4430	0.4914	0.5303	0.6188	0.4654	0.4875	0.3709	0.4545	0.4748
Nanping	0.3496	0.3610	0.2854	0.3660	0.3304	0.3540	0.3328	0.3495	0.3604	0.3362	0.5006	0.3569
Longyan	0.3202	0.3221	0.3144	0.3301	0.4291	0.3899	0.5289	0.4450	0.5636	0.4851	0.4515	0.4164
Ningde	1.0000	0.5830	0.4764	0.4559	0.7334	0.9390	0.9903	1.0000	0.9559	0.8823	0.8862	0.8093
Mean	0.6828	0.6216	0.5739	0.6108	0.6358	0.6737	0.7002	0.6875	0.6957	0.6536	0.7162	0.6592
SD	0.3236	0.2875	0.2997	0.3014	0.2849	0.2844	0.2979	0.3099	0.2916	0.2998	0.2564	
Maximum	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Minimum	0.2026	0.1931	0.1423	0.2047	0.1925	0.2276	0.1789	0.1887	0.1991	0.2263	0.3560	

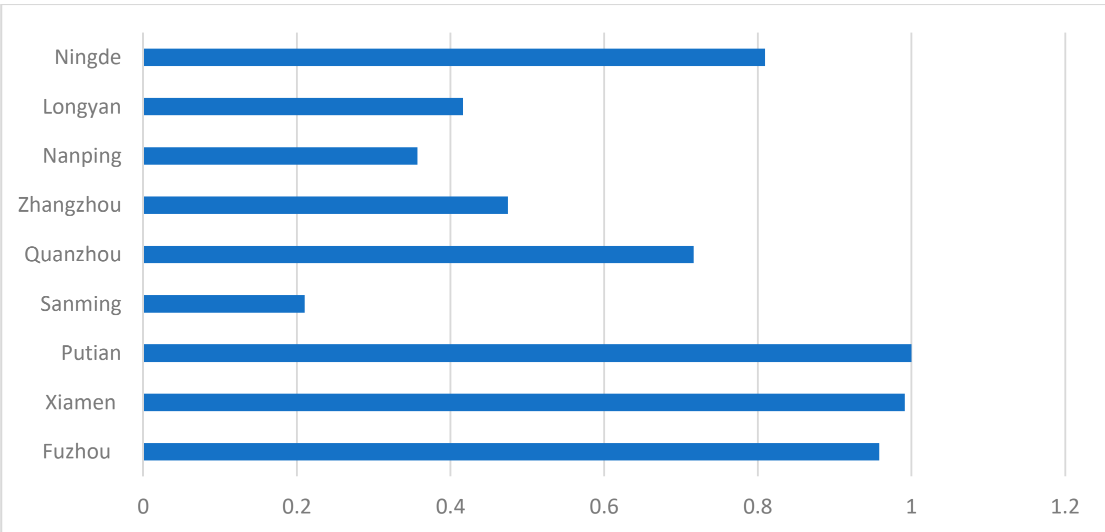

Figure 1. Average industrial ecological efficiency.

(1) On the whole, the average industrial eco-efficiency of Fujian province was 0.6592 from 2006 to 2016. Hence, it means that the industrial eco-efficiency of Fujian province still has great room for improvement and has the potential for resource conservation and pollution reduction. In 2008, the average industrial eco-efficiency of the province fell down to the lowest value of 0.5739 in past 11 years. However, it is found that overall efficiency increased with fluctuations and the average efficiency in 2016 reached the maximum value of 0.7162 during the survey period.

(2) From the perspective of the city, the differences in industrial eco-efficiency between the cities are obvious. Figure 3 clearly reflects the trend of industrial eco-efficiency in the different cities of Fujian province during the period of 2006–2016. Figure 3 shows that Putian is the most efficient city in terms of industrial eco-efficiency. It has achieved an efficiency value of 1 for 11 years and has remained stable.

Xiamen is the city with the second highest industrial eco-efficiency with an average efficiency value of 0.9913. In addition to the decrease in efficiency in 2011, Xiamen's industrial eco-efficiency of the rest of the year remained at 1 with no significant fluctuations. Fuzhou is found as the third highest industrial eco-efficiency city with an average efficiency value of 0.9579. It is found that Fuzhou's industrial eco-efficiency rises with fluctuations, but the efficiency value has remained at a relatively high level, i.e., it has remained at 1 since 2012. Ningde is the fourth highest industrial eco-efficiency in Fujian province with an average efficiency value of 0.8093. During the period, the industrial eco-efficiency of Ningde city was greatly changed showing a declining, then rising and then declining development trend. During the period between 2006 and 2013, the industrial eco-efficiency value of Ningde reached at 1. Quanzhou is the fifth largest city in terms of industrial eco-efficiency in Fujian Province with an average efficiency of 0.7165. Quanzhou's industrial eco-efficiency was found significantly fluctuating between 2006 and 2016. Moreover, an overall downward trend was observed in the mentioned period. In 2015, the eco-efficiency of Quanzhou dropped to 0.5812 as the lowest value for 11 years. Thus, the rankings of Fujian's average industrial eco-efficiency in the last four cities are Zhangzhou (0.4748), Longyan (0.4164), Nanping (0.3569), and Sanming (0.2102). The average efficiency of these cities is found below 0.6 which is significantly lower than other cities of the province.

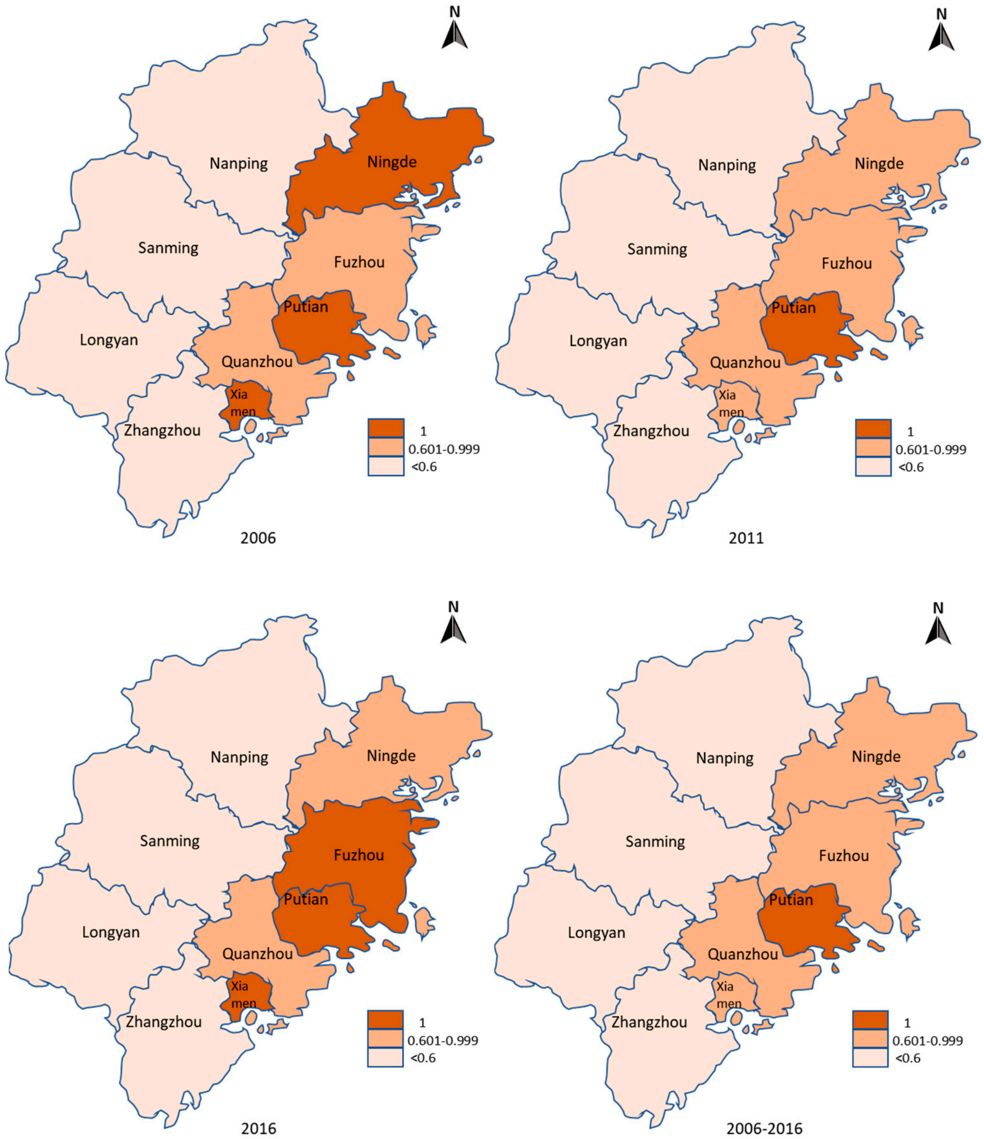

Figure 2. Spatial distribution of industrial eco-efficiency.

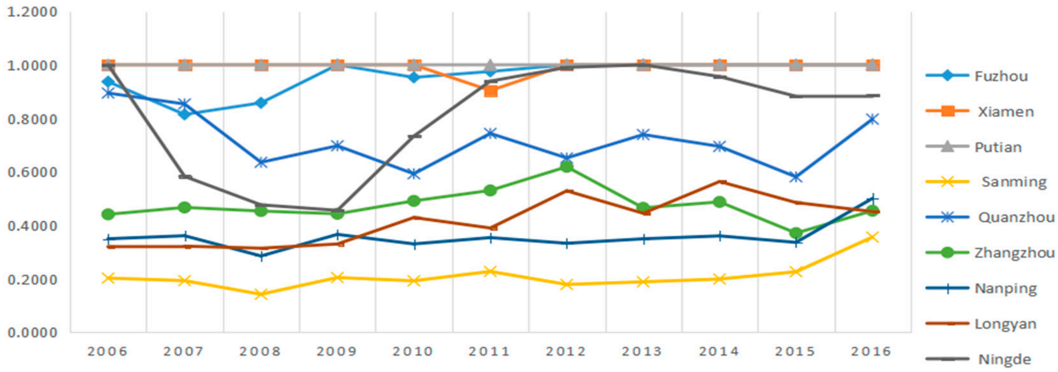

Figure 3. Line chart of industrial eco-efficiency of different cities in Fujian Province.

4.2. *Measurement and Analysis of Influencing Factors*

Due to a change in the statistical indicators and caliber, the research period of this study is defined between 2006 and 2016. The research objective is to analyze the industrial eco-efficiency of Fujian's 9 cities. In this study, Stata 12.0 analysis software is used to estimate the effects of different factors on the industrial eco-efficiency of Fujian Province, and the results are shown in Table 5.

Table 5. Tobit regression results of factors affecting industrial eco-efficiency in Fujian Province.

Variable	Parameter Estimate	Z Statistics	*p* Value
RGDP	0.1219924	0.73	0.466
UR	0.4664914 *	1.77	0.077
FDI	0.3283183 **	2.17	0.030
RDI	0.0003433 *	1.80	0.073
HEA	−0.5473832 ***	−3.36	0.001
POL	−0.9533132	−0.46	0.644
Log likelihood = 86.85789		Prob > chi2 = 0.000	

Note: ***, ** and * are respectively at the 1%, 5% and 10% significance levels.

Table 5 shows that UR, FDI, RDI, and HEA passed the significance test, among which HEA had a significant impact on industrial eco-efficiency. The RGDP and POL did not pass the significance test indicating that the two indicators have no significant effect on the industrial eco-efficiency of Fujian Province. From the empirical results, the following judgments are additionally derived:

(1) A positive correlation was found between the level of economic development and industrial eco-efficiency. The P value of RGDP was 0.466 and, hence, the regression result was not significant. It indicates that there is no obvious correlation between RGDP and industrial eco-efficiency.

(2) The correlation coefficient between FDI and industrial eco-efficiency was 0.3283 which passed the 5% significance test. It shows that foreign investment in Fujian Province has a positive effect on the improvement of regional industrial eco-efficiency

(3) A positive correlation was found between R&D innovation and industrial eco-efficiency. In the regression analysis results, the P value of RDI was 0.073 which passed the 10% significance level test. It shows that the enhancement of R&D and innovation capabilities has a positive effect on industrial eco-efficiency. However, the impact coefficient (0.000343) is relatively small.

(4) A negative correlation was found between industrial structure and industrial eco-efficiency. In the regression analysis results, the P value of HEA representing the industrial structure was 0.001 which passed the 1% significance level test.

(5) Results show that the impact of environmental regulation on industrial eco-efficiency is not significant. The proportion of investment in industrial pollution governance that characterizes environmental regulation does not affect the industrial eco-efficiency, even at the 10% level of significance.

5. Discussion and Implications

The present study shows that the current economic development in Fujian Province is at a stage where the scale effect is relatively obvious, and people's demand for the high-quality environment is not strong. Furthermore, it has been examined that structural effect is relatively weak. The impact of urbanization level on industrial eco-efficiency in Fujian Province passed the 10% significance level test, which indicates the urbanization process affects the industrial eco-efficiency of the province. Since China's reform and opening-up, the effective allocation of resources, the international division of labor and the increase in the degree of specialization have promoted regional economic development and thus improved environmental performance. Therefore, further expanding the degree of opening-up to the outside world will help improve Fujian's industrial eco-efficiency. Additionally, it shows that Fujian's R&D intensity and technology level need to be improved because its influence is not being truly exerted.

Results and analysis show that the findings of this study are consistent with the laws of industrial production. Heavy industry consumes large amounts of energy and water. Hence, heavy industry is less environmentally friendly than the light industry which may affect the quality of the environment. From this perspective, it is asserted that currently heavy industry in Fujian Province occupies a heavier position in the industrial structure, and has a greater impact on the environment, which limits the improvement of industrial eco-efficiency. This is consistent with the current situation in Fujian Province. Due to the low level of industrial development, the characteristics of heavy industry are more obvious. Hence, it is clear that the current environmental quality has been affected by industrial development. The completion of energy-saving measures is found laggard behind presenting a serious situation that demands the attention of industrial stakeholders. This shows that Fujian Province is facing greater pressure on energy and environmental emissions. Fujian Province has actively taken a series of measures to improve the overall situation, however, there are still concerns, on the one hand, whether the environmental investment has been effectively used in the provincial capacity or not. Moreover, the effect of the implementation of policies has been lagging in Fujian province. Therefore, the current relationship between environmental regulation and industrial eco-efficiency is not easy to understand and demands more research and innovation.

The present study offers some implications for policy making for the industrial stakeholders. Firstly, there is a need to accelerate and promote the optimization and upgrading of industrial structure in Fujian Province considering its regional importance. The heavy industrialization of industrial structure in Fujian Province is obvious and it is a major factor restricting the improvement of industrial ecological efficiency. Facing the situation of developing eco-friendly environment, energy conservation, and emission reduction, Fujian Province needs to actively adjust its industrial structure in order to optimize the allocation of resources, transform traditional industries, and closely follow the development opportunities of strategic emerging industries in tandem with further promoting industrial development. Eliminating outdated production capacity and promoting industrial upgrading will help the provincial industries and may concrete the pillars of Fujian's industrialization process.

Secondly, there is a need to improve the ability of scientific and technological innovation and strengthen the research and development (R&D) of green technologies in Fujian. Empirical research shows that R&D innovation has a positive impact on Fujian's industrial eco-efficiency, while technological progress is an important driving force for improving industrial eco-efficiency. However, at present, the problem of insufficient investment in scientific and technological innovation and weak scientific and technological innovation capacity in Fujian Province is relatively prominent. In particular, there are no specific measures for the investment in green environmental protection technology innovation in Fujian. The provincial authorities may consider optimizing innovative ecological environment in order to promote the transformation of research and development achievements. Moreover, improving the ability of independent innovation and promoting the progress of green technology will help Fujian to obtain industrial eco-efficiency. Fujian can make a special investment in R&D for the promotion of green innovation and may provide financial subsidies for the overall industrial eco-efficiency status. By doing so, special provincial level support could be provided to the energy conservation and environmental protection capacities, clean energy, high-tech industries, and other associated fields.

Thirdly, there is a need to improve the institutional system for environmental governance and create a "government-business-public" responsibility community in Fujian. The relationship between environmental regulation and industrial eco-efficiency is not significant and it does not play the expected role. This shows that Fujian Province has deficiencies in environmental governance investment and environmental protection policy design. Therefore, it is necessary to increase environmental governance, strengthen environmental protection supervision and establish sound responsibility system.

Fourthly, the "the Belt and Road" location-advantage should be used to deepen the level of Chinese opening to the outside world. The level of opening to the outside world in Fujian Province may have a positive effect on its industrial eco-efficiency, which may attract eco-friendly businesses from different parts of the world. Mawei's free trade zone can be helpful to further solidify the notions of eco-efficiency in Fujian Province. Due to the differences in the economic development conditions and development levels of natural resources, geographical location, and industrial structure of various regions in Fujian Province, there is a clear gap in the level of industrial eco-efficiency among various provincial regions. From this perspective, the industrial base, resources, and environmental conditions are all different. Hence, industrial stakeholders need to strengthen regional cooperation and achieve coordinated regional development in order to promote industrial eco-efficiency of the region, which may benefit the Chinese economy multifold than the current situation.

Although this study provides valuable insights, it has certain limitations as well. First, the sample data present for the period between 2006 and 2016. Although it satisfies the requirements of this study, extending the scope of the study to evaluate other periods will confirm our findings for further orientation. The present study considers the industries of various cities in Fujian Province as the research object. Future research may also consider sub-sectors of the industries within Fujian or other parts of China in order to compare and analyze the findings of present research promoting the strategy of regional industrial eco-efficiency. This study is conducted within the Chinese context; future research may extend its scope to regional contexts because of the impact of the Chinese economy on other the Belt and Road economies.

6. Conclusions

Eco-efficiency in Fujian Province is important for the revitalization of industry considering the instrumental role of this region in the promotion of the Belt and Road. The present study measures and analyzes the eco-efficiency of different cities in Fujian Province with the SBM model of undesirable outputs and Tobit regression model. This approach provides support to the existing concepts of eco-efficiency with its empirical standing to formulate more effective measures in order to promote the industrial eco-efficiency in Fujian Province and other regions. By doing so, the main factors affecting the industrial eco-efficiency in Fujian Province were encapsulated into the breadth and scope of the present study to help and cement the pillars of the theoretical and practical concepts of green industrialization. The present study additionally incorporated a Tobit regression model in order to analyze different factors influencing the industrial eco-efficiency of Fujian Province. The present study provides robust insights for the industrial stakeholders of Fujian and other associated regions of China and the Belt and Road countries which are developing business and other industrial relations with China.

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