Hindawi
Mobile Information Systems
Volume 2022, Article ID 9145294, 12 pages
https://doi.org/10.1155/2022/9145294

Research Article

Using Green IoT as a Development Path of Green Trade Economy for Ecological Sustainable Development

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Received 17 July 2022; Revised 15 September 2022; Accepted 23 September 2022; Published 6 October 2022

Academic Editor: Muhammad Zakarya

The advancement of the Internet of Things (IoT) technology and its incorporation into the trade economy has altered and improved our way of life and work. However, IoT technologies pose various issues in the green economy, including increased energy consumption, hazardous pollutants, and electronic waste. Therefore, green IoT contributes to a more environmentally friendly atmosphere that is more affordable for the green economy. As a result, it is critical to address tactics and strategies for decreasing pollution threats, traffic waste, resource utilization, energy usage, public safety, living standard, environmental sustainability, and cost management. Apart from these, the continual deepening of the trade economy has accelerated Shandong Province's rapid economic development, and the province's broad economic development mode had major negative consequences on the ecological environment. Based on the evolution of international commerce in Shandong Province and the present status of the ecological environment, this study first calculates the province's carbon emissions using the Kaya identity and derives the regression findings using the Eviews software. It examines the data link between the province's carbon emissions, energy consumption, and trade by determining the province's export carbon emissions from various industrial sectors. According to the statistics, the export carbon emissions of Shandong Province's ferrous metal rolling industry, chemical raw material production sector, and textile industry are relatively high, at 6.764 million tons, 5.502 million tons, and 3.918 million tons, respectively. The carbon emissions from the three industrial sectors mentioned above account for approximately 49% of total carbon emissions, which is a considerable reduction and in line with the concept of green IoT.

1. Introduction

The fast development and use of Information and Communication Technology are having a direct and significant influence on many parts of life, converting it from an "industrialized" civilization to a global "knowledge" society. New ICT technologies, notably the Internet of Things (IoT), are altering how individuals manage their lives, engage with one another, and participate in numerous societal domains. The Internet of Things, as a global network, involves four basic physical objects. In all, it drastically reshapes and alters the lives of individuals, companies, and society by linking individuals and things whenever, with anything and anyone, anyhow, and everywhere. As a result of the internet, mobile computing, and the Internet of Things, people, places, organizations, and infrastructure are now interconnected in unparalleled ways. Despite the enormous benefits of technological advancement and the "smartness" provided by IoT to various parts of society, their fast rise promotes greater waste, emissions of greenhouse gases, and the use of nonrenewable and natural raw materials. The resource-intensive production and distribution of ICT items and systems enhanced energy requirements throughout their use, and increasing volumes of diversified waste has the potential to hurt human health and the surroundings [1]. Thus, it poses major challenges to sustainable growth and a sustainable way of life.

As we know, several elements impact a building's energy usage, including climatic region differences, proposed methodology, construction techniques, construction material, property, and power management. The computation of carbon emissions is quite complicated. At the moment, a study on carbon emissions from structures has yielded some results based on life cycle analysis [2]. The LCA approach is primarily used to calculate a product's carbon emissions across its entire life cycle, encompassing raw materials, manufacture, usage, and destruction. We first define the boundaries of the research model, then quantify the resource consumption and carbon emissions, and lastly assess the environmental implications. The measuring method, process analysis technique [3], input-output analysis techniques [4], and hybrid approach [5] are the primary extant fundamental methodologies for quantifying carbon emissions. The hybrid approach is classified into three types depending on its composing constructions: tiered hybrid evaluation, input output-based hybrid assessment, and comprehensive hybrid assessment [6]. The hybrid analysis includes the advantages of both approaches and has recently become popular in carbon emission measurement [7]. Some researchers use basic data from the international panel on climate change to calculate total carbon dioxide emissions, however, the outcomes can only represent the entire carbon dioxide emissions of building projects, which cannot be divided into direct and indirect emissions. Carbon emissions vary throughout a building's life cycle, particularly during the embodied phase, when a high quantity of materials, construction equipment, and equipment are utilized, and diesel, petrol, electricity, as well as other sources of energy are consumed. According to research, construction materials have large carbon emissions, with indirect carbon emissions accounting for more than 92 percent [8]. The author of [9] created a hierarchical LCA system to quantify the energy consumption and environmental effect of the building sector in the United States. The IO-LCA calculates the environmental effect of the materials, and the process analysis approach is utilized to assess the environmental impact of the building phase. Nevertheless, because of the complexity of calculating carbon dioxide emissions during the integrated phase of construction, it has not been the focus of the current building carbon emissions research [10]. Carbon dioxide emissions from the building life cycle are significant in the embodied phase, accounting for about 20% [11], and some studies indicate that they can reach 40% to 45% [12]. As a result, during the embodied phase, carbon emissions have a significant influence on building carbon trading. In addition, IoT plays an important part in the growth of the green trade economy, affecting several ways through its different applications in improving community transformation. It reduces congestion, develops cost-effective municipal services, preserves people's safety and health, lowers energy usage, improves monitoring systems, and lowers pollution. However, academics have focused on IoT ecological challenges, including energy utilization, carbon emissions, energy savings, trade, carbon classification, and footprint. As a result, IoT-based carbon emission reduction and energy-saving solutions are summarized. The paper examines IoT technologies that enable real-time intelligent awareness of the environment and produce and gather energy usage throughout the production life cycle.

There are many kinds of international trade protectionism, among which green trade barriers are one. The low-carbon economy has become a basic direction of economic development in all countries and regions in the world, especially in China. It requires China to build an intensive environmental protection low-carbon foreign trade growth mode at present to replace the traditional extensive foreign trade growth mode and improve the sustainability of China's economic development [13, 14]. In the process of discussing environmental issues, the blueprint for the green economy (1989) first proposed the concept of "green economy," which is an innovative new concept. In essence, it is an economic model corresponding to the black economy [15]. The limit of growth was born in the early 1970s. This analysis report comprehensively expounds on the negative effects of environmental pollution, resource poverty, population explosion, and other negative effects caused by the one-sided pursuit of economic development. It has started and gradually triggered thinking on the direction of human development, directly impacting the traditional ideas that economic growth is equal to economic development and human conquest of nature [16, 17]. The focus of the analysis of the relationship between economic growth and resources and the environment includes two aspects. Firstly, taking the scarcity of nonrenewable resources as the starting point to analyze how resource depletion restricts the long-term economic growth rate. Secondly, focusing on the negative external effects of pollution, this paper analyzes the basic way that pollution emissions indirectly affect human long-term economic growth rate and consumption decision-making mode on the premise of the utility function and production function interference [18, 19].

The innovations of this paper are as follows: (1) this study performs an empirical analysis of the impact of green barriers on the sustainable development of China's trade in terms of green IoT. Based on the collected materials and data, this paper will explain the impact of green barriers on the sustainable development of trade from the positive and negative effects of green barriers on the quantity, amount, international competitiveness, and structure of export commodities. (2) This study explores the data relationship between the province's carbon emissions, energy consumption, and trade by utilizing Kaya identity to compute the province's carbon emissions and then obtaining the regression results with Eviews software. (3) Finally, it computes the province's export carbon emissions from various industrial sectors.

The structure of the remaining sections in the paper is organized as follows: Section 2 of the paper highlights the contributions of other researchers, scholars, and experts. Section 3 is based on the selected material and suggested methodology of ecologically sustainable development. The design of the carbon emission measurement method for ecological green trade is presented in Section 4. The analysis of the calculation results of total carbon emissions in Shandong Province can be presented in Section 5, and the work of this paper is concluded in the last section, i.e., Section 6 of the paper.

2. Related Work

The concept of green development has been formed and continuously spread. The exploration of the green development path, evaluation of green economic growth, and related theories are the focus of theoretical exploration in this field [20]. Because of the difference between the main body of green trade barriers and the degree of change, according to the gradient of its change, green trade barriers have three basic structures that are gradually progressive and change according to the gradient. To protect the ecological environment and safeguard the common interests of mankind, the international community has formulated a series of conventions, agreements, and management standards for the protection of the ecological environment since the late nineteenth century, which can be specifically divided into two categories. The first one includes some international multilateral agreements, conventions, and technical standards for the protection of the ecological environment. The purpose of formulating these public multilateral agreements and conventions is to protect the ecological environment together, there is no intention to set up technical trade barriers. The first one includes the international standards of environmental management and relevant international rules, which are aimed at the sustainable development of human beings or the protection of the life and health of human beings, animals, and plants from infringement. The formulation of these agreements, conventions, standards, and rules is dominated by developed countries, and there is often a certain range of flexible changes. Chinese scholars also analyzed the concept of green development from various angles. The path and connotation of green development are the focus of Chinese academia [21]. Research shows that the bottleneck of China's economic development has become increasingly prominent. To break this situation and ensure the sustainable development of China's economy, we must adhere to the road of green development (high efficiency, low pollution, and low-energy consumption) and pay attention to the coordinated development of environmental protection and economy [22]. Based on the perspective of "five constructions," this paper analyzes and expounds on the concept of green development and points out that the essence of green development lies in harmonious development, upward development, inclusive development, sustainable development, high-level development, and innovation-driven development [23]. In the subject of exploring the path of green development, the analysis sample selected by scholars is Anji, Zhejiang Province. They believe that it is necessary to develop a green economy with ecological civilization as the goal under the premise of combining guidance and mobilization (value level), collaborative governance of an innovative environment, and an economic operation system [24]. The green trade barrier is the product of the conflict between the environment, trade, and ecological environment. Low energy consumption efficiency, fast growth, and large total amount are the basic forms of foreign trade growth in Shandong Province [25]. From the perspective of environmental protection, the road of foreign trade with high pollution and high energy consumption in the province must be terminated, and the development mode of foreign trade must be changed, which is the basic requirement of sustainable and healthy development. Inspired from the work of above scholars, this paper first calculates the province's carbon emissions using the Kaya identity, and then, it derives the regression findings using the Eviews software. In addition, it examines the data link between the province's carbon emissions, energy consumption, and trade by determining the province's export carbon emissions from various industrial sectors.

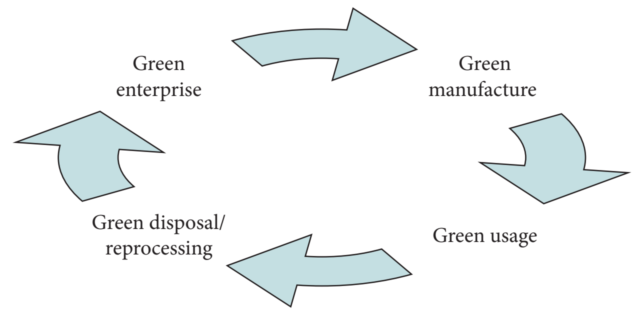

Figure 1: Life cycle of green Internet of Things.

3. Material and Methods

3.1. Material

3.1.1. Green ICT for Ecological Sustainable Development. Consumers can obtain, access, store, and manage information using green information and communications technologies (ICT) [13]. They perform an important part in greening IoT and bringing several advantages to the public, such as reducing the amount of energy consumed in developing, producing, and delivering ICT facilities and gadgets. They are fascinating, however, they have only been used in a few cases and are restricted manners. Furthermore, ICT technologies have an important role in lowering CO_2 and the consumption of energy in green IoT systems in green infrastructures, such as intelligent transportation, intelligent buildings, and parking management [26]. In this regard, the authors of [27] discussed green ICT and green IoT, which rely on a green power grid, and presented and discussed green calculating skills.

Greening IoT entails discovering novel resources, utilizing ecological maintenance, reducing the utilization of existing resources and expenses, and reducing the negative effects of IoT on the environment and human health, such as CO_2 emissions, NO_2, and other pollutants [28]. The writers of [29] presented information on how industrial emissions affect the environment through time. To make the environment healthier, Internet of Things' energy usage must be reduced [30]. Likewise, greening ICT technologies aid in ecological protection and financial development [31], and as a result, new IoT technologies have made the world greener and smarter.

3.1.2. Introduction of the Green Internet of Things. Green IoT is a low-energy method, which includes connecting devices in an energy-efficient procedure to decrease energy usage, greenhouse effects, and emissions of carbon dioxide. Green computes units, interoperability, and network-based designs with optimum bandwidth utilization and relatively

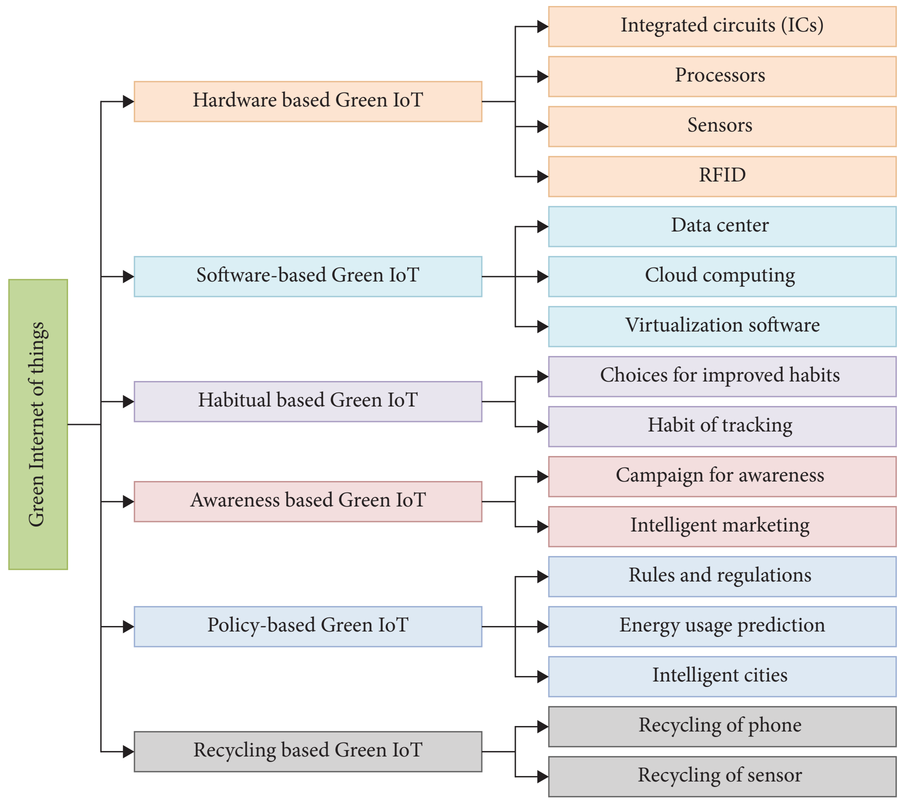

Figure 2: Organization of Green IoT skill.

minimal energy consumption. Ecological development and energy efficiency are the critical components of Green IoT. Green IoT products must pass through a closed loop that includes green design, green manufacturing, green use, and green disposal/reprocessing. Figure 1 explains the life cycle of green IoT.

(i) Green enterprise: green enterprise is the creation of energy-efficient cooling equipment, servers, computers, and components.

(ii) Green manufacturing involves the production of computers, electronic components, and other related subsystems.

(iii) Green usage: using computers and other information systems with as little electricity as possible.

(iv) Green disposal/reprocessing: it involves recycling computers and other electronic devices that are no longer in use.

The organization of Green IoT skill is shown in Figure 2.

(i) Hardware-based green IoT: the architecture of integrated circuits (ICs) is crucial for conserving energy in IoT infrastructure. Green IoT improves the IoT network design by combining sensors and computing power on a single chip to reduce infrastructure investment energy usage, carbon emissions, traffic, and e-waste. CPU-based low-energy processor that may be divided into two cores. One core is dedicated to low-computing operations, while the other is dedicated to high-computing duties. To decrease energy use, use the scheduling system to allocate jobs. The incorporation of detecting and wireless transmission has led to the creation of sensor networks. WSN is composed of a large variety of static sensor nodes that interact over short-range wireless connections and have limited processing, energy, and storage capability. Numerous inbuilt sensors on the sensor nodes may gather information from the surroundings. WSN applications help the environment by increasing resource effectiveness and lowering emissions of greenhouse gases. RFID is one of the potential green IoT wireless solutions, composed of a collection of RFID tags and a limited number of RFID tag receivers. An RFID tag is a small microchip that is linked to a radio. RFID tags have a distinct identity and may retain data about the objects to that they are connected. RFID readers initiate the information flow by sending a request signal, and the neighboring RFID tags respond. RFID tags can be passive or active, with passive tags lacking built-in batteries and relying on the notion of induction to receive energy from the prior authorization. Active tags, on the other hand, feature a battery that powers the transmitted signal and enhances the range. RFID is widely employed in applications that help to promote a better environment among many other things, increasing waste disposal, decreasing energy usage in buildings, and cutting automobile emissions.

(ii) Software-based green IoT: data centers can be key components of a power IoT network, but they need to be made highly energy-efficient for IoT to be practical. The green data center (GDC) serves as a central location for data distribution, administration, and storage. This data is created by objects, systems, users, and so on. The smartly chosen servers then send the processed information back to the client devices. Unfortunately, this approach needs the deployment of OA on every client device, in addition to the use of backup servers to provide reliability, which may lead to significant energy usage. As a consequence, to increase energy efficiency, it must feature a context-aware sensing platform that leverages choice sensing. Cloud computing is a virtualization approach that uses the internet. It offers limitless storage, processing power, and service delivery across the internet. IoT is widely used, and CC technology is widely used to link them. The primary purpose of GCC is to encourage the use of ecologically friendly materials that can be readily recycled and reused. It is possible to do this with paperless virtualization, proper power management, and allocation of resources for product lifespan. Centrally regulated data replication is essential in cloud computing to provide users with a high degree of service and reliability, however, it uses a significant amount of energy and bandwidth. A solution to reduce transmission delay is required, which might be accomplished by replicating data nearer to the consumers on cloud services. Virtualization can reduce the amount of hardware resources utilized in design, thus minimizing energy consumption.

(iii) Habitual-based green IoT: it is a small-scale metric, however, if the entire world changes to this way, it would produce a massive scale. It is accomplished by changing basic habits in our everyday life to minimize CO_2 emissions. It might be at home, office, or somewhere else.

(iv) Awareness-based green IoT: raising awareness programs are an important aspect of reducing energy use. Smart metering technology may be used to deliver real-time feedback to consumers on their power use from different sources in their buildings, workplaces, and residences. Using real-time data, green IoT may then advise clients on how to manage and reduce their energy consumption.

(v) Policy-based green IoT: policies based on available data from IoT devices have the potential to save energy on a huge scale. The process of defining rules for energy conservation includes numerous stages, involving mechanization, user feedback, information management, and tracking.

(vi) Recycling-based green IoT: the utilization of recyclable materials in the manufacturing of equipment in an IoT network can help the network to be more environmentally friendly. Mobile phones are made from valuable natural resources, such as nonbiodegradable materials, plastics, and metal, and if not disposed properly after use, they can cause the greenhouse effect.

3.2. Regional Overview of Ecological Sustainable Development

3.2.1. Geographical Location Overview. Shandong Province is located in eastern China and is one of the top ten coastline provinces in China. Figure 3 depicts the region. The province has more than 20 natural coastline outer ports with excellent geographical settings. In recent years, the Shandong provincial party committee and administration have chosen a long-term approach, increasing support for overseas commerce. Essentially, it established a multilevel, all-around, highly export competitive, and reasonably structured economy. In addition, it established a trade pattern that laid the groundwork for the steady and rapid development of province's economy and increased the province's economic development driving force, which effectively promoted the province's economic and trade development.

3.3. Overview of Shandong Trade and Economic Development Research

3.3.1. Overview of Import and Export Trade in Shandong Province. After China's reform and opening up in the 1980s, the province quickly established its own economic development goal, i.e., to develop foreign trade in an all-round way [32]. Because of the clear goal and powerful measures, the comprehensive foreign trade development achieved remarkable results. In the first decade of reform and opening up, the total foreign trade volume of the province was only US $3.417 billion (equivalent to RMB), but by 2019, the total foreign trade volume of the province had increased to US 171.06 $billion, an increase of around 50 times. The specific development of import and export trade in Shandong Province in recent ten years is shown in Figure 4.

3.3.2. Analysis on the Current Situation of the Regional Pattern of Foreign Trade in Shandong Province. Shandong Province has taken the initiative to carry out comprehensive trade exchanges with all countries and regions around the world. Up to now, the intercontinental pattern of foreign trade (mainly the European Union, North America, and Asia, supplemented by Oceania, South America, Europe, and Africa) has taken shape [33]. Table 1 shows the foreign trade data of the province and all over the world. It can be seen that the key regions of the province's foreign trade are North America, Europe, and Asia. From the overall development of the province's foreign trade market, the trade volume of North America, Europe, and Asia account for about 75%. From the perspective of geographical and economic advantages, the Asian market is the first target of the province's foreign trade, with about

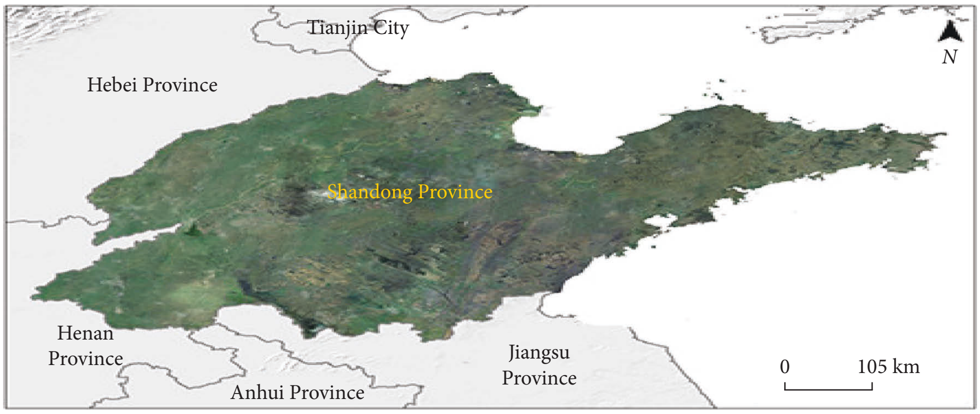

Figure 3: Schematic diagram of study area.

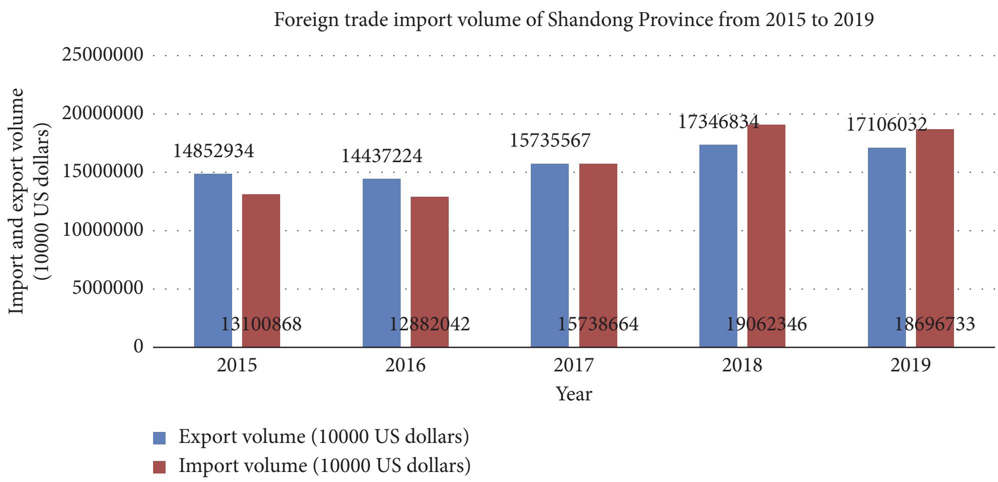

Figure 4: Change trend of import and export trade volume of Shandong Province from 2015 to 2019.

Table 1: Analysis on the regional development pattern of foreign trade in Shandong Province (proportion: %).

Region	2015	2016	2017	2018	2019
Asia	53.46	51.34	53.29	51.98	65.42
Africa	3.24	3.42	3.56	4.34	1.78
Europe	17.46	18.55	16.94	17.08	5.21
South America	4.52	5.79	7.06	6.25	19.9
North America	17.74	17.66	15.95	17.13	4.16
Oceania	3.58	3.24	3.2	3.22	5.53

51.34~65.42% of the foreign trade volume occurring in the Asian market. However, other regions outside Asia are also the key areas of long-term trade in the province, and the trade development ideas are conducive to the construction of multilevel and all-around trade relations.

3.4. Analysis of Ecological Environment in Shandong Province. The data of industrial waste gas emissions in Figure 1 below shows that the industrial waste gas emissions in Shandong Province have also increased from 3628.6 billion cubic meters in 2015 to 401.2 billion cubic meters in 2019. Industrial waste gas emissions are large. The data are shown in Figure 5. On the one hand, it significantly reduces the air quality of the province, and on the other hand, it leads to frequent haze weather in the province.

Like the development of industrial waste gas emission, industrial wastewater emission also shows an increasing trend year by year. Figure 6 shows the changes in industrial wastewater discharge in Shandong Province from 2015 to 2019. A large amount of industrial wastewater also significantly affects the natural environment, especially the water environment, and the water environment quality of nearby sea areas is significantly affected.

By analyzing the statistical data of the province (from the statistical information network), we can also see from Figure 7 that from 2015 to 2019, the province formed a discharge scale of 231.108 million tons of industrial solid

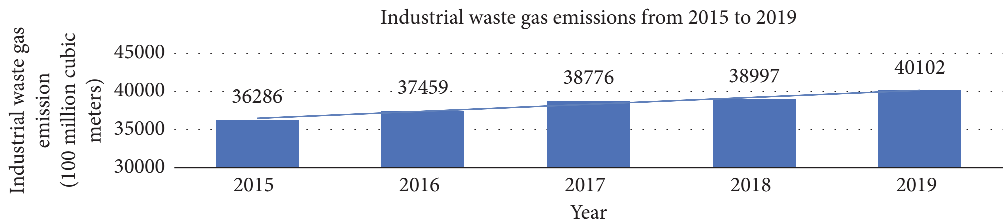

Figure 5: Industrial waste gas emissions in Shandong Province from 2015 to 2019.

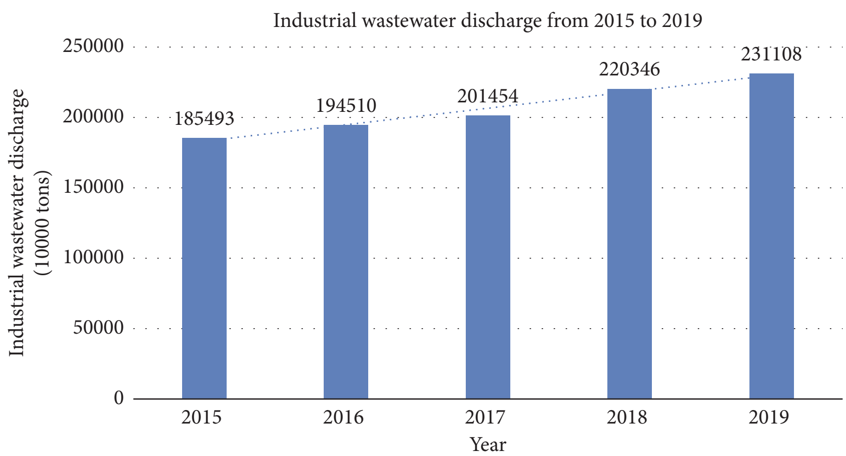

Figure 6: Changes in industrial wastewater discharge in Shandong Province from 2015 to 2019.

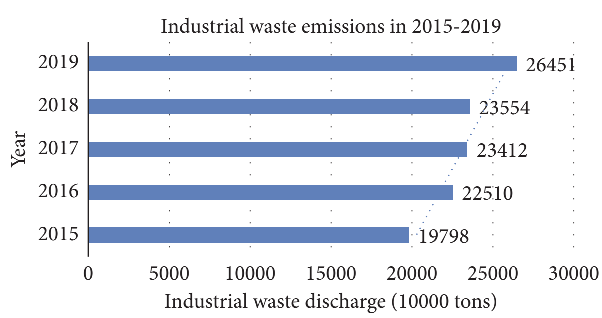

Figure 7: Change trend of industrial solid waste emissions in Shandong Province from 2015 to 2019.

waste, an increase of 456.15 million tons compared with 2015, with an average annual increase of 91.23 million tons. A large amount of solid waste discharged not only leads to the rapid expansion of land occupation but also significantly pollutes the surface and underground water bodies in the garbage storage area.

4. Design of Carbon Emission Measurement Method for Ecological Green Trade

4.1. Carbon Emission Estimation Method. At the moment, the developing world's economy is quickly expanding, and the formerly moderate growth rate of greenhouse gas emissions is accelerating, further deteriorating the worldwide ecological situation. Carbon tariffs' primary purpose is to "reduce carbon emissions," but the core of green trade barriers also exists. Developed countries or regions have completed the carbon tariff setting based on the current situation in which environmental protection issues have increasingly attracted global attention and their technology, particularly the cutting edge of emission reduction technology, which means that the economic interests of their own countries or regions are protected while the economic development competitiveness of developing countries or developing regions is significantly limited. Carbon taxes have had a substantial impact on Shandong Province's international trade [34]. Based on the reaction of green trade barriers in developed nations or regions and the resolution of economic growth obstacles, it is required to thoroughly examine the province's carbon emission status, and (1) is the carbon emission estimating equation.

$$C_t = \sum_{i}^{m} m_i \alpha_i \beta_i. \tag{1}$$

In the above equation, E_t represents the carbon emission in period t, m_i represents the consumption of the i^{th} energy, α_i refers to the conversion coefficient of the i^{th} energy into standard coal, and β_i refers to the carbon emission coefficient of the i^{th} energy.

The primary definition of energy in the study is three types of fossil energy (natural gas, oil, and coal). The energy conversion coefficient is based on data from the 2019 China Energy Statistics Yearbook, while the energy consumption data is based on the regional energy balance table (China Energy Statistical Yearbook) and the Shandong statistical yearbook. Table 2 shows the estimated energy emission coefficient based on China's Energy Research Report.

Table 2: Statistics of carbon emission coefficient of various energy sources.

Data sources	Coal	Petroleum	Natural gas	Hydropower
National development and reform commission energy research institute	0.746	0.582	0.443	0.000

4.2. Design of Ecological Green Trade and Carbon Emission Measurement Method

4.2.1. Calculation of Total Energy Carbon Emissions. Energy is a core element of product production [35]. Shandong Province is a major energy-consuming Province, and its basic energy is natural gas, oil, and coal, which are three kinds of fossil energy [36]. Carbon emission is one of the by-products of energy consumption and economic development. Foreign trade export sectors like the textile and electromechanical industries consume a lot of energy and are important foreign trade industries in Shandong Province. Such industries have a high energy consumption, which directly increases carbon emissions. Economic growth, energy consumption, and international commerce are the explanatory variables employed in this work. The model calculates the link between economic growth, energy consumption, and foreign commerce, particularly the association between carbon emissions and international trade. The (2) formula is designed to make it easier to understand the dynamic link between economic growth, energy consumption, international trade, and carbon emissions.

$$C = f(E, Y, F). \tag{2}$$

Its linear model can be specifically expressed as follows:

$$C_t = \alpha + \beta_1 E_t + \beta_2 Y_t + \beta_3 F_t + \mu_i. \tag{3}$$

In the above equation, the random coefficient term is represented by μ_i, and the total amount of import and export trade (period t) is represented by F_t. Similarly, the regional GDP (period t) is represented by Y_t with unit: 100 million yuan. Besides, primary energy consumption (period t) is represented by E_t with unit: 10000 tons of standard coal. The total carbon emission (period t) is represented by C_t with unit: 10000 tons of standard coal.

The core problem of this model is the calculation of carbon emissions, which is based on Di's decomposition equation and derived by using the Kaya identity, which can be described as follows:

$$C = \sum_i \left(\frac{E_i}{E}\right) * \left(\frac{C_i}{E_i}\right) * E = \sum_i S_i * F_i * E. \tag{4}$$

In the above equation, the carbon emission coefficient of all energy is represented by F_i, i.e., the carbon emission per unit consumed by this energy. In energy consumption, I energy accounts for S_i. The consumption of energy is represented by E_i. The total primary energy consumption (each year) is represented by E. The carbon emission of i energy is represented by C_i, and the total carbon emission is represented by C.

4.2.2. Calculation of Export Carbon Emissions of Various Industrial Sectors in Shandong Province. The calculation of CO_2 emissions from various industrial sectors in Shandong Province is the premise of the calculation of CO_2 emissions from its export trade. The energy consumption of each industrial sector in the province can be obtained from the statistical yearbook of the province. The CO_2 emission of each industrial sector is equal to the product of the CO_2 emission coefficient of each industrial sector and its energy consumption. Since the export volume of each industrial sector is known, the greenhouse gas emissions caused by the foreign trade of each industrial sector are equal to the ratio of the total export volume. Meanwhile, the entire production of each industrial sector is multiplied by the product of each industrial sector's total CO_2 emissions, as shown in equation (5).

$$C = C' * \frac{q}{Q}. \tag{5}$$

In the above equation, C is the amount of carbon dioxide produced by an industrial sector because of export trade II, C' is the carbon dioxide produced by the industrial sector, and q/Q is the proportion of the export volume of the industrial sector in the GDP.

5. Results and Analysis

5.1. Analysis on the Calculation Results of Total Carbon Emissions in Shandong Province. The total carbon emissions of the province can be obtained by calculating the carbon emissions caused by various energy consumption, which is essentially the sum of the product of the carbon emission coefficient and the total energy consumption of each kind. From the perspective of the IPCC assumption, we can assume that the carbon emission coefficient of a certain type of energy is in a stable state [37]. Based on the data released by relevant institutions of the national development and reform commission, the author determines the carbon emission coefficient of three types of fossil fuels: natural gas, oil, and coal, namely, natural gas carbon emission coefficient of 0.443, oil carbon emission coefficient 0.582, and coal carbon emission coefficient 0.747. The total carbon emissions of the province are estimated based on the statistical yearbook data of the province over the years. Change trends in carbon emissions in Shandong Province from 2015 to 2019 can be shown in Figure 8.

The regression equation between foreign trade, regional GDP, energy consumption, and carbon emissions is based on the Eviews regression analysis, which is calculated in equation (6).

$$\begin{aligned} C_t = {} & 18.291 + 0.732E_t - 0.049Y \\ & + 0.281F\,(0.0070)\,(0.0088)\,(0.0365). \end{aligned} \tag{6}$$

In regression mode, the coefficient value in brackets represent the standard error, and −53.01 is the likelihood

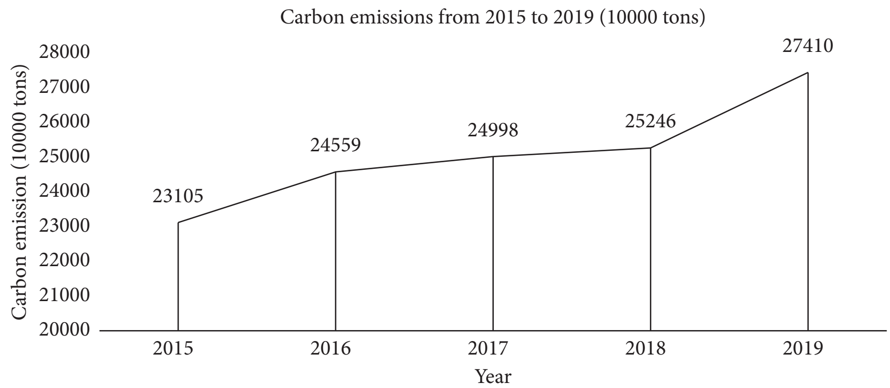

Figure 8: Change trends of carbon emissions in Shandong Province from 2015 to 2019.

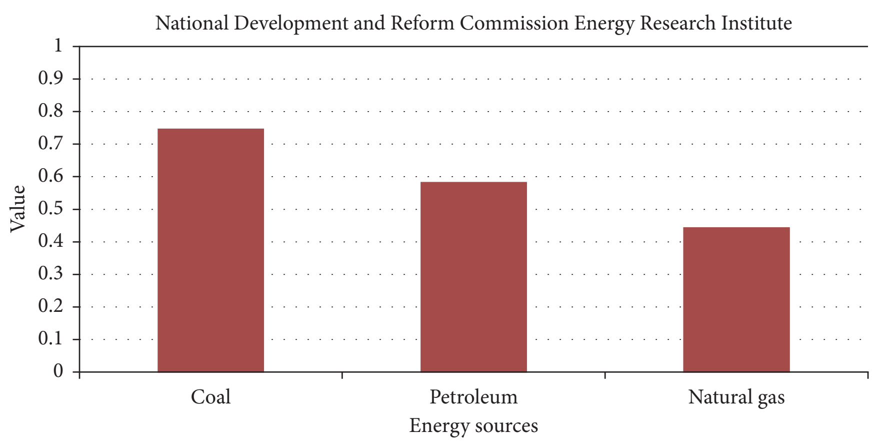

Figure 9: Comparison of data resources for the estimated energy emission coefficient based on China's Energy Research Report.

ratio of the equation. R2 is about 1, which proves to have relatively ideal goodness of fit. The analysis of the regression coefficient of explanatory variables shows that the regional GDP, namely economic growth, is inversely proportional to the total carbon emissions, and the foreign trade, energy consumption, and total carbon emissions are positively proportional.

Figure 9 compares data resources for the estimated energy emission coefficient based on China's Energy Research Report. This graph contrasts three types of fossil energy, namely natural gas, oil, and coal, which are the paper's core definitions of energy. The energy conversion coefficient in this study is based on data from the 2019 China Energy Statistical Yearbook, and the energy consumption data are from the China Energy Statistical Yearbook and the Shandong statistical yearbook.

5.2. Calculation and Analysis of Export Carbon Emissions of Various Industrial Sectors in Shandong Province. The statistics in Tables 3 and 4 of CO_2 emissions (induced by international commerce) of various industrial departments in the province show that ferrous metal smelting and calendaring ranked first, followed by the production of chemical raw materials and chemicals, and the textile sector ranked third. The top three accounted for 47.26% of the province's total CO_2 emissions from overseas trade of major industrial sectors. It demonstrates that the top three industrial sectors in Shandong Province account for a majority of CO_2 emissions from overseas trade. In essence, it is still impossible to adequately describe the structural flaws of the province's international commerce based on such data.

From the above analysis, it is clear that about 50% of the total CO_2 emissions of foreign trade in the province come from the top three departments, however, from the perspective of the total export volume of the province, the total export volume of the top three CO_2 emissions only accounts for 15.71%. For example, the food manufacturing industry, which ranks seventh in CO_2 emissions, ranks 13th in foreign trade volume. The nonmetallic mineral products business ranks sixth in terms of CO_2 emissions (2.584 million tons) but only fourteenth in terms of international trade volume. The ferrous metal smelting and rolling processing business rank first in terms of CO_2 emissions from overseas commerce (6.764 million tons) but only sixteenth in terms of export volume. The papermaking and paper products business ranks ninth in terms of CO_2 emissions but twenty-first in terms of international trade volume. Some industrial sectors with low CO_2 emissions have relatively high foreign trade volume rankings. Hence, it is the focus of the province's future development, i.e., to achieve the goal of optimizing and upgrading the province's foreign trade structure

Table 3: Carbon emission statistics of various industrial sectors in Shandong Province in 2019.

Industry	Carbon emission (10000 tons)	Industry	Carbon emission (10000 tons)	Industry	Carbon emission (10000 tons)
Ferrous metal rolling industry	3854.1	Oil and gas exploitation	295.7	Chemical fiber	76.6
Chemical raw materials and chemical products industry	3501.2	Electrical and mechanical equipment manufacturing industry	289.5	Nonferrous metal mining and beneficiation industry	46.2
Nonmetallic mineral manufacturing	2016.5	Rubber products industry	274.1	Nonmetallic mining and beneficiation industry	44.2
Petroleum refineries	1984.6	Pharmaceutical industry	169.5	Leather products industry	43.6
Nonferrous metal rolling industry	1110.8	Special equipment manufacturing	174.3	Handicraft and other manufacturing industries	42.9
Coal mining industry	1004.9	Metal products industry	168.6	Furniture manufacturing industry	38.4
Textile industry	967.3	Ferrous metal mining and beneficiation industry	155.4	Culture, education, and sports manufacturing industry	29.6
Paper industry	801.4	Wood processing and grass products industry	133.8	Printing and recording media	23.1
Agricultural and sideline food processing industry	705.5	Plastic products industry	120.1	Instrument and meter office manufacturing industry	19.5
General equipment manufacturing	581.2	Communication equipment manufacturing	108.1	Tobacco industry	7.0
Food manufacturing	327.9	Beverage manufacturing	89.4	Waste resource processing industry	4.1
Transportation equipment occupation	301.7	Textile, clothing, shoes and hats profession	78.6	Other mining industries	0

Table 4: Statistics of export carbon emissions of various industrial sectors in Shandong Province in 2019.

Industry	Carbon emission (10000 tons)	Industry	Carbon emission (10000 tons)
Ferrous metal rolling industry	676.4	Rubber and plastic products industry	311.5
Chemical raw materials and chemical products industry	550.2	Pharmaceutical industry	60.3
Nonmetallic mineral manufacturing	258.4	Special equipment manufacturing	23.1
Petroleum refineries	21.3	Metal products industry	58.2
Coal mining industry	2.9	Wood processing and grass products industry	28.4
Textile industry	391.8	Beverage manufacturing	13.1
Paper industry	90.2	Textile, clothing, shoes, and hats profession	70.0
Agricultural and sideline food processing industry	301.2	Chemical fiber manufacturing	48.4
General equipment manufacturing	71.8	Nonmetallic mining and beneficiation industry	0.5
Food manufacturing	136.5	Leather products industry	27.0
Transportation equipment manufacturing	115.2	Handicraft and other manufacturing industries	2.3
Electrical and mechanical equipment manufacturing industry	69.1	Furniture manufacturing industry	21.6
Culture, education, and sports manufacturing industry	1.8	Instrument and meter office manufacturing industry	3.6
Printing and recording media	2.5	Tobacco industry	0.2
Waste resource processing industry	0.06		

and promoting the reduction of carbon emissions from exports.

6. Conclusions

Currently, the IoT technology has reported higher benefits in improving our life quality in the green economy. Unfortunately, the growth of technology demands a large amount of energy, which is associated with unintended electrical waste and carbon emissions. This research looked at methods and ways for improving our quality of life by creating a green economy more ecological and safer. According to the computation of Shandong Province's carbon emission statistics, the province's carbon emission data from 2015 to 2019 are computed and retrieved using Excel. According to the data, the province's overall carbon emissions are growing year after year, which is divided into two stages: the first of which is 2015–2017, and this index indicates a stable development trend in this stage, while the second stage is 2018–2019 with a clear upward tendency. According to the regression coefficient, the elasticity of energy consumption in the growth process of carbon emissions is 0.732, which means that if the province's energy consumption is decreased or raised by one unit, its total carbon emissions will be lowered or increased by 0.732 units. The regression coefficient of its regional GDP is 0.049. This data shows that the province's economic development will not increase its total carbon emissions, however, its economic development has formed and promoted the emission reduction effect. The analysis shows that the proportion of some departments in the total export volume of foreign trade of the province is too heavy, and the proportion of carbon emissions of the corresponding departments in the total emissions is too large, which indicates that there are structural defects in its foreign trade. Only in this way can the goal of emission reduction and consumption reduction be achieved, the green trade economy can be made realistic, and the sustainability of the province's economic and social development be implemented.

Data Availability

The data used to support the findings of the study can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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