https://doi.org/10.21186/IPR.2022.7.2.059

# DEA모형을 이용한 중국 동부지역 대외무역의 지속가능 발전 효율성에 관한 연구

서염*, 심재연**

중국회화대학교강사*, 세한대학교 경영학과 교수**

# Study on Sustainable Development Efficiency of Foreign Trade in Eastern China Based on DEA Model

**Yan Xu*, Jae-Yeon Sim****

**Department lecturer, School of Business, Huaihua University, China***

**Professor, Dept. Of Management, Sehan University****

**요 약** 본 논문은 현재 생산량을 유지하면서 투입량을 줄이기 위해 중국 동부지역의 대외무역 지속가능 발전의 효율성을 분석하는 것을 목적으로 한다. 2016년부터 2020년까지 중국 동부 11개 성 및 도시의 관련 입출력 지표를 채택하고 DEA모형을 이용하여 종합적 효율성, 순기술 효율성 및 규모 효율성을 측정하였다. MPI 산정에 Malmquist 지수를 사용한 결과 2016년부터 2020년까지 중국 동부 전 성의 MPI는 1.035로 1보다 높았고, 순기술 효율성은 0.911로 1보다 낮았다. 전체적으로 평균 기술진보지수는 4.045로 4.5% 증가했다. 대외무역의 지속 가능한 발전 효율성은 종합적 효율성, 순기술 효율성, 규모 효율성에 전반적으로 영향을 미치고 있음을 알 수 있다. 대외무역의 지속 가능한 발전 효율성은 규모에 의해 주로 제한을 받았다. 총요인 생산성 향상은 주로 기술적 진보로 부터 효과를 얻는 것으로 나타났다. 내부요소의 영향을 받는 성들에 대해서는 내부조률을 강화하여야 한다. 외부요인의 영향을 받은 성은 외부요인에 대비해야 한다.

**주제어** 중국 동부지역, 대외무역의 지속가능 발전, 효율성, DEA, 비교연구, Malmquist 지수

**Abstract** This paper aims to analyze efficiency of sustainable development of foreign trade in eastern China to reduce the input while maintaining the current output level. This paper adopts relevant input-output indicators of 11 provinces in eastern China from 2016 to 2020 and uses DEA to measure comprehensive efficiency, pure technical efficiency, and scale efficiency from the input perspective. Malmquist index was used to calculate MPI. As a result, from 2016 to 2020, the MPI of all provinces in eastern China was 1.035, higher than 1, and the net technology efficiency was 0.911, lower than 1. Overall, the average technological progress index increased 4.5% to 1.045. It can be seen that the sustainable development efficiency of foreign trade has an overall influence on comprehensive efficiency, net technology efficiency, and scale efficiency. The efficiency of sustainable development of foreign trade in eastern China is mainly limited by its scale. The improvement of MPI in the eastern Region mainly benefits from technological progress. For provinces affected by internal factors, it is suggested to strengthen internal coordination. For provinces affected by external factors, it is suggested to respond appropriately to external factors.

**Key Words** Eastern China, Sustainable Development of Foreign Trade, Efficiency, DEA, Malmquist Index

* This Paper was supported by the Sehan University Fund in 2022.

Received 29 Mar 2022, Revised 07 Apr 2022

Accepted 21 Apr 2022

Corresponding Author: Jae-Yeon Sim

(Sehan University)

Email: simjy@sehan.ac.krr

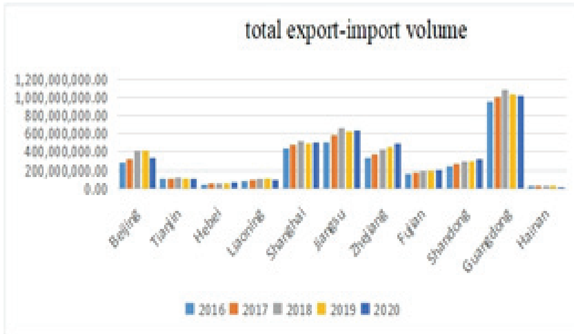
ISSN: 2466-1139(Print)

ISSN: 2714-013X(Online)

# 1. Introduction

## 1.1 Research Background

According to China's new accelerating economic and social development situation, the country is divided into four regions: the Eastern Region, northeast Region, Central Region, and Western Region. The main contents of economic and social development in each Region are as follows: the eastern Region takes the lead in development, the northeast rejuvenates, the central Region rises, and the western Region develops. The Eastern Region covers 11 provinces and cities, including Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. Promoting the eastern Region to take the lead in development is an essential strategic plan for regional economic layout based on China's actual development and internal laws of its economy. Since 1980s, China has successively set up five special economic zones in Shenzhen, Zhuhai, Shantou, Xiamen, and Hainan and has opened up the Yangtze river delta, the pearl river delta, and other coastal economic open zones, thus opening a new chapter of China's regional economic development. After entering the new century, the Eastern Region has been entrusted with the historical mission of pioneering high-quality development. The Eastern Region has always been the "top student" in China's opening-up pattern. In 2020, foreign investment in the eastern Region increased by 8.9%, accounting for 88.4 %. Shandong and Zhejiang, the central provinces attracting foreign investment, increased by 20.3% and 18.3 %, playing a solid driving role. In the first three quarters of 2021, China used 859.51 billion yuan of foreign investment, up 19.6 percent year on year, and continued to optimize the structure of the inward investment. In the future, according to the requirements of the 14th Five-Year Plan, the eastern Region will participate in international economic cooperation and competition at a higher level, build new advantages in opening up to the outside world, and take the lead in establishing an all-round open economic system.



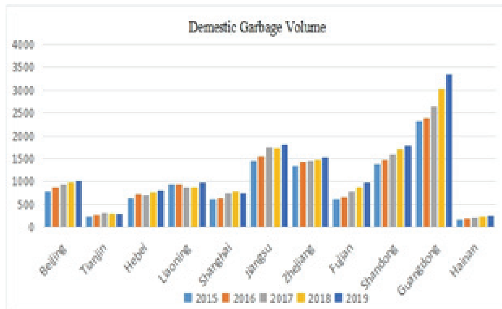

[Figure 1] Total Import and Export Volume of Eastern China from 2016 to 2020

Since the reform and opening up, foreign trade, together with consumption and investment, has become the "troika" driving China's rapid economic growth. According to the statistics of China Customs, in 2020, the total value of import and export in eastern China was 3.8 billion YUAN, down 0.15% year on year, among which export was 2.1 billion yuan, up 2.18%, the import was 1.7 billion yuan, down 2.86%, and the trade surplus was 400 million yuan, up 38%. In increasing downward pressure on the domestic economy, foreign trade has played a crucial role in supporting economic growth. Figure 1 shows that during the five years from 2016 to 2020, eastern China's total import and export volume showed an overall upward trend in all years except 2020 when it declined due to the impact of COVID-19. Guangdong, Jiangsu, Shanghai, Zhejiang, and Beijing were the top five. The total import and export volume of Hainan province, Hebei Province, and Liaoning Province ranks behind. In particular, the total import and export volume of Hainan province is minimal, as shown in Figure 1, showing a large gap with Guangdong Province. It can be seen that the total amount of foreign trade in the eastern provinces and cities is unbalanced.

The rapid development of foreign trade has achieved rapid economic growth and caused great harm to the environment. For a long time, the development model of foreign trade in eastern China has been the extensive trade mode of "high investment, high consumption, high pollution, and low income." The vast majority of intermediate products and finished products exported will cause severe pollution to the environment and waste many resources. In recent years, the consequences brought about by this extensive trade development mode, which only relies on quantitative expansion to achieve trade growth, have gradually emerged. On the one hand, export products depend heavily on resources, but the utilization rate of resources is meager.

On the other hand, the unrestrained exploitation of resources and excessive damage to the environment results in a large amount of waste of resources, severe environmental pollution, and lack of economic development. Therefore, to some extent, the trade development in eastern China is at the cost of environmental pollution and resource consumption. The faster the trade development is, the more resources will be consumed, and the greater the environmental pollution. Environmental and resource problems affect the speed and efficiency of the development of foreign trade itself and restrict the speed and efficiency of the development of the whole national economy to a great extent, making the foreign trade in eastern China face more and more severe challenges.

From the perspective of ecologically sustainable development, the author took the domestic garbage collection volume in the net discharge of three wastes in foreign trade as an example. The author consulted China Statistical Yearbook in recent five years, and the domestic garbage collection volume of provinces and cities in eastern China from 2016 to 2020 is shown in Figure 2. In eastern China, the domestic garbage volume collected from 2016 to 2020 showed an increasing trend, and the top five provinces were Guangdong, Jiangsu, Shandong, Zhejiang, and Liaoning. Guangdong province, in particular, is a large province of import and export volume, as well as a large province of waste discharge.




[Figure 2] Domestic Waste Volume in Eastern China from 2016 to 2020

How to realize the quantitative growth of foreign trade in eastern China while ensuring the improvement of foreign trade-economic quality, how to realize the coordinated development of population, resources, environment, and trade, and how to measure the effectiveness of this coordinated development have become the focus of many scholars. Therefore, the first question is to how to improve the economic quality of foreign trade while increasing the quantity of foreign trade in eastern China. Namely, it is about the problem of sustainable development of foreign trade in eastern China. The second question is how to measure the sustainable development efficiency of foreign trade in eastern China.

### 1.2 Research Objectives and Research Significance

In this paper, the data envelopment analysis (DEA) method is adopted to analyze the efficiency of sustainable development of foreign trade from 2016 to 2020 based on the statistical data of foreign trade in eastern China from the perspective of input and output combined with the indicators of sustainable development of foreign trade and further analyzes the factors causing non-DEA effectiveness. Then it evaluates the sustainable development of foreign trade in eastern China in the recent five years. Moreover, the Malmquist productivity index is used to dynamically analyze the efficiency changes in eastern China from 2016 to 2020, and the impact of technological efficiency changes and technological progress on total factor productivity are studied. Compared with the central and western regions, the Eastern Region has a higher level of economic development and obvious geographical advantages, so it is easy to blindly expand investment in foreign trade activities, resulting in the waste of resources. Therefore, this paper chooses an input-oriented to reduce the input in the Eastern Region while keeping the current output level unchanged to reduce the waste of resources.

Sustainable development refers to “the development that meets the needs of the present generation without compromising the ability of future generations to meet the needs." It includes three interrelated parts: sustainable economic development, sustainable social development, and sustainable ecological environment development, and it is a complex systematic project. So, understanding the present situation of the eastern China foreign trade sustainable development, setting up foreign trade sustainable development ability evaluation index, and analyzing foreign trade sustainable development efficiency in eastern China through the empirical analysis, have a specific reference value on the research of China's trade economy and resource environment coordinated development, also help to understand the relationship between trade and environment. Similarly, the research on the sustainable development capacity of foreign trade has specific theoretical and practical significance for formulating China's trade policy and improving the trade model.

## 2. Previous Research

From the perspective of the research process, the academic circle carried out the theoretical discussion of “the connotation and realization of sustainable development of foreign trade” in the early stage. The content mainly includes the connotation of sustainable development of foreign trade, implementation conditions, policy selection, dynamic evolution mechanism, and the correlation analysis of the environment and foreign trade development. Moreover, the empirical analysis of “how to measure the level of sustainable development” has gradually become the focus of attention. However, if there is no scientific index evaluation system and method, the idea of sustainable development can only become a mere formality, which can neither clearly define the connotation of sustainable development nor be used to guide practice. Compared with the theoretical discussion, the empirical research on measuring the level of sustainable development of foreign trade in academia is relatively lagging.

### 2.1 Connotation of Sustainable Development of Foreign Trade

For the social and economic benefits caused by foreign trade, scholars mainly evaluate from two aspects: one is to measure the direct contribution of foreign trade to GDP growth in a certain period; the second is to measure whether the foreign trade sector has positive spillover to other sectors of the national economy. Considering that all kinds of spillover effects of foreign trade will eventually affect GDP growth, most scholars start by examining the correlation between foreign trade and GDP growth and seek answers to the above two questions under the framework of two mechanisms of the researcher's role. Generally speaking, there are two types of empirical research methods under this research framework. The first type is to roughly calculate the direct contribution of foreign trade to GDP using the national income identical equation (Lin Yifu, 2001). The second is to determine the concrete value of foreign trade's contribution to GDP growth by analyzing the input-output table (Chen Xikang, 2001).

As for the ecological benefits of foreign trade, scholars mainly focus on analyzing the environmental costs caused by foreign trade. (1) Expand the 2×2×2 Heckschel-Ohlin model by introducing environmental factors, and then try to quantitatively study the environmental impact of free trade between countries with different environmental factor endowments (Murrell. P, Ryteman. R., 1991); (2) Using the "computable general equilibrium" model or local equilibrium model to directly analyze the environmental impact of the export of resource-intensive primary products; (3) Draw the environmental Kuznets curve of trade development to analyze the correlation between foreign trade and environmental quality. Other scholars tried to conduct empirical studies on China's export growth (Zhang Lianzhong et al., 2003; Li Xiuxiang and Zhang Ting, 2004).

According to the concept of sustainable development of foreign trade elaborated by WTO, it contains trade growth, environmental protection, and social equity. The sustainable development of foreign trade refers to improving the social, economic, and ecological, environmental benefits of a country or Region through foreign trade activities, rather than just one aspect. Therefore, many scholars have carried out studies on the comprehensive measurement of sustainable development level of foreign trade in recent years (Yang Hongyi, 2008; Chen Qiufeng, 2008).

### 2.2 Evaluation Indicators of Sustainable Development Efficiency of Foreign Trade

Yuan Yongyou and Liu Jianming (2004) first proposed that six factors should be considered in evaluating the sustainable development capacity of foreign trade, including total volume, economic benefit, chemical benefit, technological benefit, ecological benefit, and resource benefit. Zhou Maorong and Zhou Nianli (2005) tried to create a layered 13 evaluation index system to measure sustainable export development from social and economic benefits and ecological benefits of export trade. Yang Hongyi (2008) divided the economic benefit index, ecological benefit index, and social benefit into three index levels divided explicitly into 24 indicators. Zhang Xin and Yu Meng (2009) constructed 15 indicators from six aspects: the full scale of foreign trade, foreign trade benefits, foreign trade-economic benefits, foreign trade technical benefits, ecological benefits, and foreign trade resource benefits. Peng Jing and Gu Guoda (2010) constructed an indicator system of sustainable development of foreign trade with 22 indicators to increase trade scale, trade structure, industrial structure, economic benefits, resource benefits, and ecological benefits. Ouyang Qiang and Xie Xichen (2012) constructed an evaluation system for the sustainable development of regional foreign trade composed of two system layers, seven target layers, and 22 indicators. Hong Jinduan, Yi Luxia, and Sun Meinan (2013) further refined 22 three-level indicators from three aspects of economic, social, and environmental.

### 2.3 Using DEA Method to Evaluate the Efficiency of Sustainable Development of Foreign Trade

Wan Li (2020) took nine cities in the Guangdong-Hong Kong-Macao Greater Bay Area as DMU and applied BCC(Banker、Charnes and Cooper) model to analyze sustainable development efficiency of foreign trade in the Greater Bay Area from 2010 to 2016, so as to improve the efficiency. Wu Kexin (2018) constructed a scientific evaluation index system for the efficiency of sustainable development of foreign trade and established a data envelope score by using the relevant data information of Jilin Province's foreign trade during 2011-2015 By analyzing the model and using the principal component analysis method, the problem of too many indexes is solved. The main factors affecting the sustainable development efficiency of Jilin province's foreign trade are quantitatively discussed, and the sustainable development efficiency is objectively evaluated. Yang Qian (2018) used the three-stage DEA model to select relevant data and information of China's foreign trade from 2012 to 2016 and conducted research from the perspective of input-output. Zhang Ruqing (2020) analyzed and evaluated the export efficiency and influencing factors of 16 prefecture-level cities in Anhui Province based on the DEA and panel regression models. Zhou Xiaomeng (2016) made a comparative analysis of the sustainable development ability of foreign trade of 29 Provinces in China through the DEA model and obtained the ranking of the sustainable development ability of foreign trade of all provinces. Zhang Baoyou and Huang Zuqing (2012) used the DEA model to study the sustainable development efficiency of Zhejiang's foreign trade based on the foreign trade-related statistical data of Zhejiang province from 2000 to 2008 and analyzed the factors causing non-DEA effectiveness, and proposed improvement measures for existing problems. Zhao Jingmin (2007) used the DEA method to study and analyze the sustainable development efficiency of foreign trade in Jiangsu Province and put forward corresponding countermeasures according to the research results.

In previous research, how to realize the increase in the number of China's foreign trade, how to improve and enhance the quality of foreign trade and how to realize the coordinated development of population, environment and trade were studied. However, research on efficiency of foreign trade sustainable development research is still insufficient, which has not attracted attention of many scholars. Therefore, this paper intends to adopt the method of data envelopment analysis (DEA) and combine the indicators of sustainable development of foreign trade from input and output. Based on the relevant statistical data of foreign trade in eastern China from 2016 to 2020, this paper analyzes the sustainable development efficiency of foreign trade in eastern China from 2016 to 2020, further analyzes the factors causing non-DEA effectiveness, and then evaluates the sustainable development of foreign trade in eastern China in the past five years. In addition, the Malmquist productivity index is used to dynamically analyze the changes of efficiency in eastern China from 2016 to 2020, and the impact of technological efficiency changes and technological progress on total factor productivity are studied. Then it evaluates the sustainable development of foreign trade in eastern China in the recent five years and analyzes the evaluation results to improve the effectiveness of the sustainable development of foreign trade in eastern China.

At present, no scholars have used the DEA model to analyze the efficiency of sustainable development of foreign trade in eastern China. Therefore, the study in this paper will be a solid supplement for this field.

The innovation of this paper still lies in the empirical object. A large number of literature have discussed the definition of sustainable development capacity of foreign trade and the construction of sustainable development capacity evaluation indicators. A few pieces of literature have carried out empirical research on the sustainable development capacity of trade of a single province, but there are few comparative studies involving various provinces. This paper analyzes the comparative situation of the trade sustainable development capacity of 11 provinces and cities in eastern China and innovation in the empirical object.

## 3. Research Methods

### 3.1 Evaluation Model Based on DEA

Data Envelopment Analysis (DEA) is a systematic analysis method developed by A. Charnes and W.W.

Cooper based on relative efficiency evaluation(Charnes, A. , Cooper, W. W. , Golany, B. , Seiford, L. , & Stutz, J. . (1978). Foundations of data envelopment analysis for Pareto-Koopmans efficient empirical production functions. Econometrics, 30( 1-2), 91-107.). DEA method takes the weight coefficients of input and output indexes of decision making units as optimization variables, and projects decision making units onto DEA front surfaces by means of mathematical programming. DEA makes a comprehensive evaluation on the relative effectiveness of decision making units by comparing the deviation degree of decision making units from DEA frontier, and can obtain a lot of management information reflecting decision making units.

Foreign trade sustainable development is the basic idea of foreign trade to maximize value (social value and economic value) while minimizing resource inputs and pollution of the environment. It means using the least amount of resources and environmental cost (loss) to obtain the maximum social and economic value, consistent with the DEA method of input and output index requirements. Therefore, it is feasible to evaluate the sustainable development of foreign trade by the DEA method.

### 3.2 Malmquist Index Method

The Malmquist index method is based on the DEA model, which uses distance function ratio to analyze input-output efficiency. On the one hand, the Malmquist index can be used to measure and obtain information to find out the contribution of changes in pure technical efficiency and scale efficiency to changes in technical efficiency. On the other hand, if non-technical efficiencies occur, it is possible to determine how much of it is caused by pure technical inefficiencies and scale inefficiencies, thus providing correct guidance for improvement.

In the empirical analysis part of this study, the Malmquist index method of DEA is used to measure and analyze the changes of total factor productivity (TFP) of 11 provinces and cities in eastern China.

### 3.3 Selection of Input-output Indicators

By studying the construction of the evaluation index system of the sustainable development capacity of foreign trade by the above scholars, combining the actual situation of the development of foreign trade in eastern China and referring to the evaluation index system of the sustainable development capacity of foreign trade in the previous research literature, this paper considers the sustainable development of foreign trade economy, society, and ecology. It selects the following evaluation indicators (as shown in Table 1).

〈Table 1〉 Input-output indicators

| level indica tors | secondary indicators | Level 3 indicators | indicator type |
|---|---|---|---|
| Evaluation | economic sustainability | import and export volume X1 | output |
| | | Provincial GDP X2 | output |
| | | FDI X3 | input |
| | social sustainability | Employment in foreign trade X4 | input |
| | | Per capita income of foreign trade industry X5 | output |
| | ecological sustainability | net emissions of three wastes X6 | input |

The meanings of indicators in this paper are as follows: import and export value X1 is equal to the sum of import and export value, which is used to observe the full scale of foreign trade in a region. Gross Domestic Product (GDP) X2, an indicator used to measure the state of a region's economy. FDI utilized(X3) represents capital input because FDI plays an essential role in developing foreign trade in eastern China and is one of the essential sources of sustainable development construction funds. Because the statistical department has no employment statistics for employees in the foreign trade industry, this paper adopts the employment situation of employees in cities and towns of various provinces to replace the number of employees in the foreign trade industry X4, which reflects the human resources invested in the development of foreign trade in a region, and the smaller the value, the better. The per capita income of foreign trade industry X5 is expressed by the average income of employees in cities and towns of each province. The higher the value is, the more foreign trade brings to the people. The net discharge of foreign trade three wastes X6 is calculated by the net discharge of industrial wastewater, waste gas, and waste residue. Due to the unavailability of wastewater and waste gas data, this index is calculated by the net discharge of waste residue. The larger the value is, the greater the damage to the environment caused by foreign trade activities. In addition, among the six tertiary indicators, X1, X2, and X5 are income-oriented (output) indicators. The higher the value is, the higher the sustainable development level of foreign trade is. X3, X4, and X6 are cost (input) indicators. The smaller the value is, the higher the sustainable development level of foreign trade is.

### 3.4 Data Sources and Research Objects

In this paper, the input (X1, X2, X5) and output (X3, X4, X6) data of 11 provinces and cities in eastern China are sorted out and plotted according to the Statistical Yearbook of 11 provinces and cities in eastern China from 2016 to 2020 and the statistical bulletin of national economic and social development from 2016 to 2020. The research object (DMU) is 11 provinces and cities in eastern China.

## 4. Empirical Analysis

Combined with the relevant data of input-output indicators in Table 1, this paper uses DEAP 2.1 software to calculate the relevant data and finally obtains the sustainable development efficiency of foreign trade of 11 provinces and cities in eastern China.

### 4.1 Analysis of DEA Static Results

Panel data of 11 eastern provinces from 2016 to 2020 were selected for analysis. Some of the missing values are filled with linear interpolation.

DEA model is divided into input-oriented and output-oriented. The objective of the input-oriented analysis is to minimize input while maintaining the current output level. The output-oriented analysis aims to achieve the highest output level given the input. Compared with the central and western regions, the Eastern Region has a higher level of economic development and obvious geographical advantages, so it is easy to blindly expand investment in foreign trade activities, resulting in the waste of resources. Therefore, this paper chooses an input-oriented to reduce the input and waste of resources in the Eastern Region while keeping the current output level unchanged. Therefore, both DEA and Malmquist analyses only analyze BCC-I and CCR-I models.

#### 4.1.1 Comprehensive Efficiency Analysis

First, the CCR model with the constant return to scale is used to calculate the technical efficiency of sustainable development of foreign trade. Then BCC model with the variable return to scale is used to decompose the technical efficiency into pure technical efficiency and scale efficiency. DEAP 2.1 was used to process the sample data. By applying the CCR model and BCC model in the DEA method, the comprehensive efficiency, pure technical efficiency, and scale efficiency of each province and city are measured, and the value range is 0-1. When the efficiency value is 1, DEA is effective. The CCR model is used to measure the comprehensive efficiency TE, whose value is given in Table 2.

〈Table 2〉 Technical Efficiency

| DMU | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| Beijing | 0.898 | 0.733 | 0.786 | 1.000 | 0.873 |

| | | | | | |
|---|---|---|---|---|---|
| Fujian | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Guangdong | 1.000 | 1.000 | 1.000 | 1.000 | 0.999 |
| Hainan | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Hebei | 0.979 | 1.000 | 0.955 | 0.870 | 0.871 |
| Jiangsu | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Liaoning | 1.000 | 1.000 | 0.823 | 0.911 | 0.752 |
| Shandong | 1.000 | 0.952 | 1.000 | 0.936 | 0.906 |
| Shanghai | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Tianjin | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Zhejiang | 0.891 | 0.887 | 0.919 | 1.000 | 1.000 |
| Avg. | 0.979 | 0.961 | 0.953 | 0.974 | 0.946 |
| effective quantity | 8 | 8 | 7 | 8 | 6 |

Technical efficiency reflects the overall situation of resource allocation in foreign trade activities. Overall, the average technical efficiency of each province in the Eastern Region from 2016 to 2020 is 0.963, close to 1, indicating that the technical efficiency of the sustainable development of foreign trade in the Eastern Region is good. In different years, the average technical efficiency between 2016 and 2020 decreased from 0.979 in 2016 to 0.946 in 2020. The number of influential provinces and cities remained in the range of 7-8 provinces in 2016-2019 and decreased to 6 provinces in 2020, indicating that the average technical efficiency showed an overall regression trend. From different provinces, Fujian, Guangdong, Hainan, Jiangsu, Shanghai, Tianjin and the technical efficiency of a total of five provinces and cities average is 1, the DEA efficiency, up about 45.45% of the sample provinces, has reached the technical efficiency frontier, these provinces mainly located in the Yangtze River delta and the pearl river delta, relatively reasonable resource allocation structure in foreign trade activities. The average technical efficiency of Beijing, Hebei, Liaoning, Shandong, and Zhejiang is less than 1, which is still far from the frontier. These provinces are mainly located in the Beijing-Tianjin-Hebei Region and the Bohai Rim region, which need to optimize further their foreign trade activities' input and output structure.

#### 4.1.2 Pure Technical Efficiency Analysis

In order to further study the efficiency of the sustainable development of foreign trade in eastern China, the pure technical efficiency values of 11 provinces and cities in eastern China are calculated by using the BCC model based on variable returns to scale and the pure technical efficiency values of each province are analyzed. Table 3 shows the pure technical efficiency values of 11 provinces and cities in eastern China from 2016 to 2020.

Pure technical efficiency reflects the management and system level in foreign trade activities. Overall, each province's average pure technical efficiency in the Eastern Region from 2016 to 2020 is 0.979, close to 1, indicating that foreign trade management and sustainable development in the Eastern Region is good. From different years, the overall trend of pure technical efficiency decreases. The average pure technical efficiency decreased from 0.99 in 2016 to 0.962 in 2020. The number of effective provinces decreased from 9 to 8. The quantity ratio of effective provinces fell from 81.82% to 72.73%. From the perspective of different provinces and cities, the mean pure technical efficiency of Beijing, Fujian, Guangdong, Hainan, Jiangsu, Shanghai, and Tianjin is 1, accounting for 63.64% of the sample provinces a high level of management and system. The average pure technical efficiency of Hebei, Liaoning, Shandong, and Zhejiang is less than 1, mainly located in the Bohai Rim region, which needs to further optimize its management and system-level.

〈Table 3〉 Pure Technical Efficiency

| DUM | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| Beijing | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Fujian | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Guangdong | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Hainan | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Hebei | 0.987 | 1.000 | 0.960 | 0.896 | 0.896 |
| Jiangsu | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

| | | | | | |
|---|---|---|---|---|---|
| Liaoning | 1.000 | 1.000 | 0.826 | 0.946 | 0.765 |
| Shandong | 1.000 | 0.952 | 1.000 | 0.991 | 0.917 |
| Shanghai | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Tianjin | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Zhejiang | 0.899 | 0.896 | 0.920 | 1.000 | 1.000 |
| Avg. | 0.990 | 0.986 | 0.973 | 0.985 | 0.962 |
| effective quantity | 9 | 9 | 8 | 8 | 8 |

#### 4.1.3 Scale Efficiency Analysis

Scale efficiency reflects the gap between the existing scale of foreign trade and the optimal scale. Overall, the average scale efficiency of all provinces and cities in eastern China during 2016~2020 is 0.983, close to 1, indicating that scale efficiency is relatively high. From the perspective of different years, the scale efficiency decreased from 0.989 in 2016 to 0.983 in 2020, showing a slight regression trend. Each year's adequate quantity and proportion were consistent with the technical efficiency, which decreased from 72.73% to 54.55%. By comparing pure technical efficiency and scale efficiency, it can be found that pure technical efficiency is lower than scale efficiency, on the whole, indicating that the existing sustainable development efficiency of foreign trade in eastern China is mainly restricted by its scale level.

〈Table 4〉 Scale Efficiency Analysis

| DMU | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| Beijing | 0.898 | 0.733 | 0.786 | 1.000 | 0.873 |
| Fujian | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Guangdong | 1.000 | 1.000 | 1.000 | 1.000 | 0.999 |
| Hainan | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Hebei | 0.992 | 1.000 | 0.994 | 0.971 | 0.972 |
| Jiangsu | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Liaoning | 1.000 | 1.000 | 0.996 | 0.962 | 0.983 |
| Shandong | 1.000 | 1.000 | 1.000 | 0.944 | 0.988 |
| Shanghai | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Tianjin | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Zhejiang | 0.991 | 0.990 | 0.999 | 1.000 | 1.000 |
| Avg. | 0.989 | 0.975 | 0.980 | 0.989 | 0.983 |
| effective quantity | 8 | 8 | 7 | 8 | 6 |

### 4.2 Malmquist Index Results and Dynamic Analysis

Only static comparisons can be made when using DEA method to analyze efficiency, but dynamic comparisons cannot be made. Dynamic changes of efficiency of each DMU cannot be analyzed during the sample period. At this point, the Malmquist productivity index method is introduced. Malmquist index was used to calculate the total factor productivity change index (MPI, Malmquist Productivity Index) of sustainable foreign trade development in eastern provinces from 2016 to 2020, and it was decomposed into technological efficiency change index of sustainable foreign trade development and technological progress index of sustainable foreign trade development from the perspective of constant return to scale.

DEAP 2.1 was used to investigate the efficiency changes of the BCC-I model in four periods in eastern China: 2016-2017, 2017-2018, 2018-2019, and 2019-2020. See Table 5, Table 6, and Table 7 for details.

#### 4.2.1 Analysis of Total Factor Productivity Change Index

MPI is called the change index of total factor productivity, greater than or equal 1. Internal factors are also called technical efficiency TCI. External factors are also known as technological progress TECT. MPI is influenced by both internal factor TCI and external factor TECI. Comparing TCI and TECI values, which is more extensive, has a more significant impact on total factor productivity MPI.

〈Table 5〉 Total Factor Productivity

| DMU | 2016-2017 | 2017-2018 | 2018-2019 | 2019-2020 | Avg. |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Beijing | 0.861 | 1.178 | 1.168 | 0.842 | 0.999 |
| Fujian | 1.016 | 1.244 | 0.996 | 0.953 | 1.046 |
| Guangdong | 1.131 | 1.033 | 1.024 | 0.966 | 1.037 |
| Hainan | 1.050 | 1.036 | 1.183 | 0.731 | 0.985 |
| Hebei | 1.034 | 1.051 | 0.964 | 0.939 | 0.996 |
| Jiangsu | 1.059 | 1.094 | 1.067 | 0.969 | 1.046 |
| Liaoning | 1.110 | 1.141 | 1.170 | 1.054 | 1.118 |
| Shandong | 1.030 | 1.336 | 1.080 | 0.953 | 1.091 |
| Shanghai | 1.040 | 1.219 | 1.085 | 0.922 | 1.061 |
| Tianjin | 1.109 | 1.017 | 0.943 | 0.935 | 0.999 |
| Zhejiang | 1.035 | 1.951 | 0.743 | 0.702 | 1.013 |
| Avg. | 1.041 | 1.188 | 1.031 | 0.900 | 1.035 |

Overall, the MPI of all provinces in eastern China from 2016 to 2020 is 1.035, indicating that the average annual growth rate of the total factor productivity of the sustainable development of foreign trade in eastern China has reached 3.5%. Among them, the mean values of the MPI index in Fujian, Guangdong, Jiangsu, Liaoning, Shandong, Shanghai, and Zhejiang provinces are all greater than 1, accounting for 63.64% of the sample provinces. Among them, the annual growth rate of Shandong province reached the highest 9.1%, indicating that its sustainable development efficiency of foreign trade has made significant progress. The MPI index of Beijing, Hainan, Hebei, and Tianjin are all less than 1. These provinces and cities are mainly located in the Beijing-Tianjin-Hebei Region, and total factor productivity shows a trend of regression as a whole. Hainan province saw the most significant drop of 1.5 percent.

#### 4.2.2 Analysis of Technical Efficiency Change Index

On the whole, the mean of technical efficiency change index of each province from 2016 to 2020 is 0.991<1, with an average annual decline of 0.9%, indicating that the technical efficiency of sustainable development of foreign trade in eastern China has declined, which is consistent with the conclusion above. The highest growth rate was 2.5 percent in 2018-19, and the lowest growth rate was 3.2 percent in 2019-20. Only Liaoning saw its average technical efficiency above 1, increasing by 2.9 percent among different provinces. EC index of Fujian province, Hebei Province, Jiangsu Province, Shandong Province, Tianjin, And Zhejiang Province is equal to 1, and the whole is in an inactive state, with neither significant progress nor significant regression. The above analysis shows that the technical efficiency of these provinces and cities is equal to 1 in 2016-2020 and has reached the frontier of technical efficiency, so there is no room for further improvement. The change index of total factor productivity is mainly dominated by technological progress. EC of Beijing, Guangdong province, Hainan Province, and Shanghai were all less than 1, showing a significant regression. Hainan province had the lowest EC value of 0.931, decreasing by 6.9%.

〈Table 6〉 Technical Efficiency Change Index

| DMU | 2016-2017 | 2017-2018 | 2018-2019 | 2019-2020 | Avg. |
|---|---|---|---|---|---|
| Beijing | 0.816 | 1.073 | 1.272 | 0.873 | 0.993 |
| Fujian | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Guangdong | 1.021 | 0.955 | 0.911 | 1.002 | 0.971 |
| Hainan | 1.000 | 0.823 | 1.106 | 0.826 | 0.931 |
| Hebei | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Jiangsu | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Liaoning | 0.995 | 1.037 | 1.088 | 1.000 | 1.029 |
| Shandong | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Shanghai | 0.952 | 1.051 | 0.936 | 0.969 | 0.976 |
| Tianjin | 1.000 | 1.000 | 1.000 | 0.999 | 1.000 |
| Zhejiang | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Avg. | 0.979 | 0.992 | 1.025 | 0.968 | 0.991 |

#### 4.2.3 Analysis of Technological Progress Index

Overall, each province's average technological progress index from 2016 to 2020 was 1.045, increasing by 4.5%. It shows that the technological progress of the sustainable development of foreign trade in the eastern Region shows an overall growth trend. The growth rate peaked at 19.7 percent in 2017-2018 and was less than 1 percent in 2019-20, showing a 7 percent regression. From the perspective of different provinces, except Hebei province and Tianjin, the technological progress index of the other nine provinces and cities is greater than 1, showing an increasing trend. Shandong, Shanghai, and Liaoning provinces saw the highest technological progress of 9.1 percent, 8.7 percent, and 8.6 percent, respectively. The TC index of Hebei province and Tianjin city is less than 1, with a decline of 0.4% and 0.1%, respectively, indicating that technological progress needs improvement.

〈Table 7〉 Technological Progress Index

| DMU | 201-2017 | 2017-2018 | 2018-2019 | 2019-2020 | Avg. |
|---|---|---|---|---|---|
| Beijing | 1.055 | 1.098 | 0.918 | 0.965 | 1.006 |
| Fujian | 1.016 | 1.244 | 0.996 | 0.953 | 1.046 |
| Guangdong | 1.107 | 1.082 | 1.125 | 0.964 | 1.068 |
| Hainan | 1.050 | 1.258 | 1.070 | 0.885 | 1.057 |
| Hebei | 1.034 | 1.051 | 0.964 | 0.939 | 0.996 |
| Jiangsu | 1.059 | 1.094 | 1.067 | 0.969 | 1.046 |
| Liaoning | 1.116 | 1.101 | 1.075 | 1.054 | 1.086 |
| Shandong | 1.030 | 1.336 | 1.080 | 0.953 | 1.091 |
| Shanghai | 1.092 | 1.161 | 1.159 | 0.952 | 1.087 |
| Tianjin | 1.109 | 1.017 | 0.943 | 0.936 | 0.999 |
| Zhejiang | 1.035 | 1.951 | 0.743 | 0.702 | 1.013 |
| Avg. | 1.063 | 1.197 | 1.006 | 0.930 | 1.045 |

By comparing the technical progress index and technical efficiency index, it can be found that the technical progress level of the Eastern Region is higher than the technical efficiency, indicating that the improvement of the total factor productivity of the sustainable development of foreign trade in the eastern Region mainly benefits from its technical progress level. Regarding technical efficiency, the optimal allocation of resources needs to be further improved.

## 5. Conclusion

This study uses DEA and Malmquist index method to analyze the input efficiency of sustainable foreign trade development in Eastern China from 2016 to 2020. DEA was used to measure the comprehensive efficiency, pure technical efficiency, and scale efficiency of 11 provinces and cities in eastern China from 2016 to 2020. Malmquist Productivity Index was used to analyze the dynamic changes of efficiency in 11 provinces and cities in eastern China from 2016 to 2020, and the impact of technological efficiency changes and technological progress on total factor productivity was studied. The main conclusions are as follows:

The sustainable development efficiency of foreign trade in 11 provinces and cities in eastern China is estimated using the data enveloping analysis method. Overall, the average technical efficiency of provinces and cities in eastern China is close to 1 from 2016 to 2020, indicating that foreign trade's sustainable development technical efficiency in eastern China is good. From the point of view of different years, the average technical efficiency showed a regression trend. Provinces with effective DEA are mainly located in the Yangtze River Delta and Pearl River, and foreign trade activities' resource allocation structure is relatively reasonable. Provinces with ineffective DEA are mainly located in The Beijing-Tianjin-Hebei Region and the Bohai Rim region, so the input and output structure of their foreign trade activities is needed to optimize.

Overall, the average pure technical efficiency of all provinces and cities in eastern China from 2016 to 2020 is close to 1, indicating that foreign trade management and sustainable development in eastern China are good. From different years, the overall trend of pure technical efficiency decreases. The Beijing-Tianjin-Hebei Region, the Yangtze River Delta, and the Pearl River Delta have high management and institutional levels, while the average pure technical efficiency of Hebei, Liaoning, Shandong, and Zhejiang, which are located in the Bohai Rim region, is less than 1, which requires further optimization of their management and institutional levels. Overall, the average scale efficiency of all provinces and cities in eastern China during 2016-2020 is close to 1, indicating that scale efficiency is relatively high. From the perspective of scale efficiency in different years, there was a slight regression trend. By comparing pure technical efficiency and scale efficiency, it can be found that pure technical efficiency is lower than scale efficiency, on the whole, indicating that the existing sustainable development efficiency of foreign trade in eastern China is mainly restricted by its scale level.

Overall, the MPI of all provinces in eastern China from 2016 to 2020 is 1.035, indicating that the average annual growth rate of the total factor productivity of the sustainable development of foreign trade in eastern China has reached 3.5%. The mean values of MPI in the Yangtze River Delta and The Pearl River Delta are more significant than 1. Shandong province has the highest annual growth rate, indicating that its sustainable development efficiency of foreign trade has made significant progress. In contrast, Hainan province has the highest decline, and the factor productivity of all provinces and cities in the Beijing-Tianjin-Hebei Region shows a regression trend.

In general, the technical efficiency of sustainable development of foreign trade in all provinces and cities in eastern China declined from 2016 to 2020. Shanghai and Shanghai's technical efficiency change index (EC) were both less than 1, indicating a significant decline. On the whole, the level of technological progress of sustainable development of foreign trade in all provinces and cities in eastern China showed an increasing trend from 2016 to 2020. Except for Hebei province and Tianjin, the technological progress index of the other nine provinces and cities is greater than 1, showing an increasing trend. Comparing the technological progress index and technical efficiency index, it can be found that the technological progress level is higher than that of technical efficiency, which indicates that the improvement of MPI of sustainable development of foreign trade in eastern China mainly benefits from its technological progress level. In a word, the effect of external factors is greater than that of internal factors. Regarding technical efficiency, the optimal allocation of resources needs to be further improved.

For those provinces and cities affected by internal factors, it is suggested to strengthen internal coordination, restructure and improve operations. Those provinces and cities affected by external factors need to respond appropriately to external factors such as government policies, economic environment, social environment, or technological development to improve efficiency.

In a word, to improve the efficiency of the sustainable development of foreign trade in eastern China, the key lies in developing countermeasures based on its actual situation and characteristics and continuously improving its management level, technical capacity, and optimal allocation resources.

In this paper, the sustainable development efficiency of foreign trade of 11 provinces and cities in eastern China is analyzed, and the influence of technical efficiency change and technological progress on total factor productivity is studied. However, due to data availability, this study's selection of input-output indicators is not comprehensive enough, which can be further expanded in the future. The improvement plan of low-efficiency provinces and cities should be further studied, such as the AHP method.

There are some limitations in this study, which are mainly reflected in the following aspects:

In terms of selecting input and output indicators, the input and output indicators selected in this paper have certain limitations. There are many factors affecting the sustainable development of foreign trade. This paper considers foreign trade's economic, social, and ecologically sustainable development to determine the input-output indicators. Foreign trade net discharge of three wastes as one of the input indicators reflects the sustainable development of ecology. Due to the unavailability of wastewater and exhaust gas data, the net discharge of waste residue replaces the net discharge of three wastes in this input index. The results would be more accurate if more input-output indicators were added.

(2) The foreign trade efficiency calculated by the DEA model in this paper is absolute value rather than relative value, so it is not suitable for comparative analysis. For example, the comprehensive technical efficiency of Fujian province and Guangdong province is 1, which only means that the absolute value of the comprehensive technical efficiency of the province is 1. Therefore, three-stage DEA model research is needed in the future.

(3) The improvement plan for low-efficient provinces and cities needs further study, such as the AHP method(Analytical Hierarchy Process). In future research, efficiency prediction can be carried out. Establishing an efficient evaluation and prediction mechanism can help the government analyze current development and early warning of future changes.

## References

[1] Zhang, B. Y., & Huang, Z. Q. (2012). Evaluation of sustainable development efficiency of Foreign trade in Zhejiang Province based on DEA. Journal of International Economics and Trade, 28 (2), 25-34.
DOI: 10.13395 / j.carol carroll nki. Issn. 1009-0061.2007.03.002

[2] Lin, Y. F., & Li, Y. J. (2001). Necessary Correction -- A reexamination of the relationship between foreign trade and China's economic growth. International Trade, (9), 22-26.
DOI: 10.3969 / j.i SSN. 1002-4999.2001.09.005

[3] Chen, X. K. (2001). Input-occupancy output technology and its application. Policy and Management, (12), 39.
DOI: CNKI: SUN: ZCGL. 0.2001-12-010

[4] Murrell, P., & Ryterman, R. (1991). A Methodology for Testing Comparative Theories:Economic Theory and Application to East-West Environmental Problems. Journal of Comparative Econimics, 15(4), 582-601.
DOI: 10.1016/0147-5967 (91) 90002 - B

[5] Zhang, L. Z., & Zhu, T. (2003). Analysis of the impact of trade liberalization on China's environmental pollution. Nankai Economic Research, (3), 3-5.
DOI: 10.3969 / j.i SSN. 1001-4691.2003.03.001

[6] Yang, H. Y. (2008). Evaluation and empirical analysis of Anhui Province's foreign trade sustainable development ability. Technical Economics, (12), 65-69.
DOI: 10.3969 / j.i SSN. 1002-980 - x. 2008.12.012

[7] Chen, Q. F. (2008). Connotation and evaluation index of sustainable development of foreign trade. Jiangsu Business Theory, (6), 62-63.
DOI: CNKI: SUN: SAHG. 0.2008-06-024

[8] Yuan, Y. Y., & Liu, J. M. (2004). Thinking on the establishment of China's foreign trade sustainable development evaluation index system. Problems in International Trade, (1), 32-36.
DOI: CNKI: SUN: GJMW. 0.2004-01-007

[9] Zhou, M. R., & Zhou, N. L. (2005). An empirical study on the sustainable development level of China's export trade - based on the time-series data from 1985 to 2003. Journal of Quantitative And Technical Economics,(11),11-26.
DOI: 10.3969 / j.i SSN. 1000-3894.2005.11.002

[10] Zhang, X., & Yu, M. (2009). Dynamic analysis of sustainable development capacity of Foreign trade in Liaoning Province. China Commerce and Trade, (15), 154-155.
DOI: 10.3969 / j.i SSN. 1005-5800.2009.15.099 밭

[11] Peng, J., & Gu, G. D. (2010). Research on the index system of sustainable development of regional foreign trade -- based on the empirical

analysis of Zhejiang Province. Journal of Business Economics and Management, (12), 46-50.
DOI: 10.14134 / j.carol Carroll nki cn33-1336 / f 2010.12.014
[12] Ouyang, Q., & Xie, X. C. (2012). Construction and application of evaluation index system for sustainable development of foreign trade: A case study of Hunan Province. Journal of International Business and Economics, (1), 15-25.
DOI: 10.13509 / j.carol Carroll nki. Ib. 2012.01.011
[13] Hong, J. D., Yi, L. X., & Sun, M. N. (2013). Evaluation of sustainable Development of Export Trade in Guangdong Province. Ecological Economy, (08), 87-91.
DOI: 10.3969 / j.i SSN. 1671-4407.2013.08.018
[14] Wan, L. (2020). Study on the efficiency of sustainable development of foreign trade in Guangdong-Hong Kong-Macao Greater Bay Area-based on DEA model. Journal of Tianjin Vocational College of Commerce, 8(5), 18-22.
DOI: 10.16130 / j.carol Carroll nki. 12-1434 / f 2020.05.003
[15] Wu, K. X. (2018). Research on sustainable development efficiency of Foreign trade in Jilin Province. Journal of Hubei University of Science and Technology,38 (1),25-31.
DOI: 10.16751 / j.carol Carroll nki. HBKJ. 2018.01.005
[16] Yang, Q. (2018). Efficiency analysis of China's foreign trade sustainable development based on three-segment DEA model. Statistics and Management, (6), 7-9.
DOI: 10.16722 / j.i SSN. 1674-537 - x. 2018.06.002
[17] Zhang, R. Q., & Huang, S. J. (2020). Measurement and influencing factors of Export efficiency in Anhui Province. Journal of Hefei University of Technology (Social Science Edition), 34(4), 1-7.
http://www.cnki.com.cn/Article/CJFDTotal-HFGS202004001.htm
[18] Zhou, X. M. (2016). Research on the evaluation of Sustainable development capacity of China's foreign trade based on PCA-DEA method. Hunan University, Master thesis.
DOI: CNKI: SUN: SLTJ. 0.2013-02-005
[19] Zhao, J. M . (2007). Efficiency evaluation of Jiangsu Province's foreign trade sustainable development based on DEA. Jiangsu Economics and Trade, (3), 7-9.
DOI: 10.13395 / j.carol carroll nki. Issn. 1009-0061.2007.03.002

**서 염(Xu Yan)**

- 2007년 7월~현재: 회화대학교 경제학과 강사
- 2019년 12월~현재: 세한대학교 경영학 (경영학박사 재학)
- 2007년 6월: 중남재경정법대학 (경제학석사)
- 2005년 7월: 연산대학 국제경제 및무역학과 (경제학학사)
- 관심분야 : 경제, 무역
- E-Mail: 363879538@qq.com

**심 재 연 (Sim, Jae-Yeon)**

- 1985년 2월: 조선대학교 회계학과 (경영학학사)
- 1990년 2월: 조선대학교 대학원 회계학과 (경영학석사)
- 1995년 2월: 조선대학교 대학원 경영학과 (경영학박사)
- 1995년~현재: 세한대학교 경영학과 교수
- 관심분야: 회계정보시스템, 정부회계, 인적자원관리
- E-Mail: : simjy@sehan.ac.kr