Thesis for the Degree of Master of Business Administration

The Determinants of Green Total Factor Productivity in Chinese Shipbuilding Industry

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Approval Page

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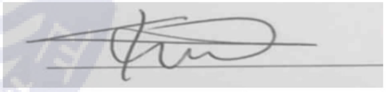

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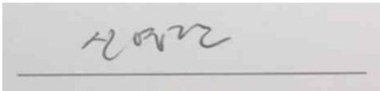

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The Determinants of Green Total Factor Productivity in Chinese Shipbuilding Industry

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ABSTRACT

The shipbuilding industry is a strategic industry that promotes the upgrading of Chinese industrial structure, and it is also the only industry that can compete with rivals in developed countries. Since the implementation of the reform and opening-up policy, the price advantages of raw materials, labor and land have supported the rapid growth of China's economy for many years, the export of the shipbuilding industry has also been rapidly expanding. However, at present, Chinese shipyards are mainly engaged in labor-intensive, low value-added ship construction in the international ship market, and staying at the bottom of the "smiling curve" of the manufacturing industry. Additionally, the market prices of domestic raw materials, labor, land and energy have gradually increased in recent year, and other developing countries in the world have actively participated in the international market at a lower factor input cost, which has caused concerns about the loss of competitiveness of the shipbuilding industry. In addition, China's shipbuilding industry, as a pollution-intensive heavy industry, is also facing increasingly tight environmental regulations at home and abroad. How to maintain the competitiveness while investment in environmental protection is a matter of concern for industry entrepreneurs strengthening and scholars. Green manufacturing is a manifestation of the sustainable development strategy of the shipbuilding industry, and it can also make shipyard stand out from their competitors. Taking into consideration of resources and environmental factors at the same time to evaluate the green total factor productivity index of China's shipbuilding industry is an effective method to analyze industrial development.

To begin with, the panel model system was used to examine the effects of capital labor input, energy input, and pollution emissions on the green total factor productivity of China's shipbuilding industry. The green total factor productivity of China's shipbuilding industry shows a certain cyclical change, which is mainly explained by the market's cyclical influence. Observing the data of various regions, the growth of green total factor productivity of China's shipbuilding industry result from the combined effect of green technological progress and green technical efficiency. The average value of green total factor productivity of China's shipbuilding industry is lower than total factor productivity average, which means the evaluation method of China's shipbuilding industry productivity without considering environmental regulations partially overestimated the total factor productivity. Then, based on the absolute β convergence test to analysis the differences in the growth of green total factor productivity of the shipbuilding industry in various regions. Results tell that the shipbuilding industry as a whole has an absolute convergence trend and tends to equilibrium. Meanwhile, the convergence of the three major shipbuilding centers in the east,

middle and west regions of China's shipbuilding industry shows a clear convergence trend in each shipbuilding center. In a word, the internal growth difference of the development of China's shipbuilding industry gradually decreases with time.

Further step, the dynamic panel model is adopted to perform regression analysis on the determinants of green total factor productivity in China's shipbuilding industry. Considering the time lag of technological progress, the analysis finds that R&D investment often promotes the increase of green total factor productivity in future. At the same time, considering the completion of the environmental governance infrastructure, it will continue to affect the environmental performance. The lag of green total factor productivity was introduced to explore the way of improving the green competitiveness from a comprehensive perspective. The conclusion shows that a higher technical level can significantly increase green TFP, and excessive dependence on the international market hinders the growth of the green TFP. Environmental regulation has brought about a "compensation effect" on the growth, which supports the "Porter Hypothesis" theory.

Based on theoretical and empirical analysis, the policy enlightenment for improving the green total factor productivity of the shipbuilding industry is given. Compared with the existing research on the productivity of the shipbuilding industry, the innovation of this research is reflected in the following three aspects:

First, introducing unexpected output indicators and internalizing environmental factors into the input-output model, innovatively evaluating the green total factor productivity of China's shipbuilding industry. Which draw a new view that the green total factor productivity of Chinese shipbuilding industry was lower than traditional total factor productivity.

Secondly, comparative analysis of traditional total factor productivity and green total factor productivity, a comprehensive investigation of the decomposition index of green total factor productivity of China's shipbuilding industry. This research tested the convergence of the growth of green total factor productivity of the shipbuilding industry in various regions. The results show that the green total factor productivity of the shipbuilding industry in various regions increasingly converge.

Finally, a dynamic panel model is established with environmental regulation as the main independent variable, while the macroeconomic situation, technological progress, and export dependence are controlled variables. The conclusion offers evidence to support "Porter Hypothesis" that environmental regulation has a positive effect to the development of Chinese shipbuilding industry.

KEY WORDS**:** Green TFP, Environmental Regulation, Technical Innovation, ML Productivity Index, Shipbuilding Industry

중국 선박공업의 녹색전요수생산률에 영향요인 분석

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요 약

조선산업은 중국의 산업구조에서 전략적인 산업이며, 선진국과 경쟁할 수 있는 유일한 산업이기도 하다. 개혁개방 이후에 원자재, 노동력, 토지 등의 가격 우위를 중심으로 중국 경제의 성장을 견인해 왔으며, 조선업의 수출도 빠르게 성장하고 있다. 그러나 현재 중국 조선소는 국제선박시장에서 노동집약적이고 부가가치가 낮은 선박 건조에 주력하고 있으며, 제조업의 ' SMILE CURVE'의 밑바닥에 위치해있다. 그리고 최근 몇 년 동안 국내 원자재, 노동력, 토지와 에너지의 시장가격이 점점 오르고 있으며, 제3의 개도국에서 더 낮은 요소 원가 우위를 바탕으로 국제시장에 참여하고 있는 실정이다. 이에 따라 환경 오염을 유발하는 조선산업에 대한 국내 외 환경규제가 강화되고 있어서, 중국의 조선산업의 경쟁력을 유지하기 어려운 상황에 처해 있다. 이에 따라 녹색 제조는 조선산업의 지속적인 성장을 위한 방법으로, 자원과 환경 요인을 함께 고려하며 중국의 조선산업의 녹색 총요소 생산성지수를 평가하는 것은 산업 발전을 분석하는 효과적인 방법이다.

따라서 본 연구에서는 패널 모델링 시스템을 사용하여 노동 투입, 에너지 투입과 오염 배출과 관련하여 중국 조선산업의 녹색 총요소 생산성에 미치는 영향을 살펴보고자 하였다. 실증 분석 결과를 살펴 보면, 중국 조선산업의 녹색 총요소 생산성은 일정한 주기적 변화를 보이고 있으며 이는 주로 시장의 주기적 영향으로 해석되었다. 지역별 데이터를 바탕으로 살펴보면, 중국 조선산업의 녹색 총요소 생산성 증가가 녹색 기술 진보와 녹색 기술 효율의 시너지 효과로 나타난 것을 알 수 있다. 중국 조선산업의 녹색 총요소 생산성 평균치가 총요소 생산성 평균보다 낮다. 이는 환경 법규를 고려하지 않은 채 전통적인 평가 방법 부분에서 총요소 생산성을 높게 평가했음을 의미한다. 그리고 절대 베타수렴검사에 기초해 지역별 녹색 총요소 생산성 증가의 차이를 분석하였다. 그 결과 중국의 신조 발주량은 절대적으로 증가 추세이며 균형을 이루고 있다. 또한, 중국 동부, 중부, 서부 3개 주요 조선센터의 수렴치는 조선센터마다 뚜렷한 융합 추세를 보이고 있다. 요컨대 중국 조선업 발전의 내부 성장의 차이는 시간이 갈수록 줄어들고 있다고 볼 수 있다.

또한, 중국 조선산업의 녹색 총요소 생산성 결정 요인을 동적 패널 모델로 회귀 분석을 실시하였다. 기술 진보의 시차를 감안하였으며, 분석결과 연구개발 투자가 미래의 녹색 총요소 생산성 향상을 촉진한다는 것을 확인하였다. 이와 더불어 환경관리 인프라 정비가 환경성과에 계속 영향을 미칠 수 있다는 점도 고려하였다. 그리고 녹색 총요소 생산성의 지체 항목을 도입해, 녹색 경쟁력을 높이는 방법을 종합적으로 검토하였다. 따라서 높은 기술 수준은 녹색 총요소 생산성을 현저하게 높일 수 있다. 반면, 국제 시장에 대한 과도한 의존은 녹색 총요소 생산의 성장을 저해하고 있다. 환경 규제가 녹색 전 요소 생산성 성장에 보상 효과를 가져왔는데, 이는 “포트 가설“ 이론으로 검증되었다.

따라서 선행연구와 실증분석 결과를 바탕으로 조선산업의 녹색 총요소 생산성을 높이는 정책적 시사점을 제시하고자 한다. 기존의 중국 조선산업의 녹색 총요소 생산성 연구와 비교하여 본 연구의 다음과 같은 세 가지 측면에서 시사점이 있다.

첫째, 우선 비기대산출지표를 도입해 환경요인을 투입산출모델에 내부화하고, 중국 조선산업의 친환경 총요소 생산성을 평가하였다. 그리고 중국 조선산업의 녹색 총요소 생산성이 전통적인 총요소 생산성보다 낮다는 새로운 관점을 제시하였다.

둘째, 전통적인 총요소 생산성과 녹색 총요소 생산성의 비교 분석을 통해, 중국 조선산업의 녹색 총요소 생산성의 분해 지표를 종합적으로 고찰하였다. 그 결과, 각 지역 조선산업의 녹색 총 요소 생산성이 갈수록 같아지고 있는 것으로 확인하였다.

마지막으로, 환경규제를 주요한 자체변수로 하는 동적 패널 모델을 구축하였으며, 거시경제 추세로 기술진보와 수출의존도가 제어변수로 사용하였다. 이를 통해 '포터 가설'을 뒷받침하는 증거를 제시함과 동시에 환경 법규가 중국 조선산업 발전에 긍정적인 역할을 한다는 중요한 단서를 제공하였다.

KEY WORDS : 녹색전요소 ; 환경규제 ; 기술진보 ; ML생산성지수 ; 선박공업

CHAPTER 1: INTRODUCTION

The Club of Rome submitted to the United Nations a report entitled "The Limits of Growth" in 1972. The report summarized global issues into five areas, namely world population, food supply, industrial growth, environmental pollution and non-renewable resources. The materials of human social life and production mainly come from the environment and resources. With the increasingly sharp contradiction between global resources and environment and economic development, more and more scholars have begun to pay attention to the relationship between economic growth and environment. Since the reform and opening up, China's economy has been based on high investment in production factors, and the rapid development of the domestic economy has formed a "Chinese miracle." However, excessive consumption of natural resources and very serious environmental pollution bring the heavy costs to China. Taking the shipbuilding industry as an example, it has quickly become the world's largest shipbuilding country under the policy advantage, but the shipbuilding industry as a pollution-intensive industry should not be underestimated for environmental pollution. This chapter summarizes the research in terms of research background, purpose and significance, as well as literature review, research framework, major innovations and shortcomings.

1.1 RESEARCH BACKGROUND

As a traditional industry facing marine transportation, the shipbuilding industry provides the necessary guarantees for maritime trade, marine exploration, and naval equipment. It is also known as the shipbuilding industry or shipbuilding industry. It has gathered a lot of labor, capital, and technology. As a pillar industry of the national economy, every aspect of the shipbuilding industry, from design to production, is associated with many industries and is linked to the development of the macroeconomic economy. It is called "the crown of comprehensive industry". In addition, history has proved that the shipbuilding industry is an important reserve force for the navy's national defense. During the war, commercial ships could be quickly converted into warships. Due to the high degree of integration in the technology development of the shipbuilding industry, military technology in the shipbuilding industry is easily converted into civilian technology.

After World War II, the world's shipbuilding industry moved from Europe to East Asia. Japan seized the favorable opportunity of a large number of ships at home and abroad and quickly supported the development of Japanese shipyards. In 1956, the number of shipbuilding completions took over the United Kingdom for the first time, ranking first in the world. South Korea followed closely, vigorously supporting South Korean shipyard enterprises and quickly occupying the international market during the prosperity of the marine market. In 1999, South Korea took over Japan for the first time to become the world's largest shipbuilding country. In contrast, although China has a long history of shipbuilding, the starting point of the shipbuilding industry lags behind Japan and South Korea. After 2000, China began to support the shipbuilding industry as a national strategic industry, and introduced many unprecedented support policies. At present, China's shipbuilding industry is huge and already in a leading position in the global market. The three major shipbuilding indicators continue to lead the world. However, China's shipbuilding industry still lags behind the developed countries in terms of independent ship design, and the upstream and downstream industries supporting the shipbuilding industry also lag significantly. At the same time, the lack of advanced production management concepts and relatively weak technological innovation capabilities restrict China in many ways development of the shipbuilding industry. After the Asian financial crisis, major Japanese shipping companies have tried to improve production efficiency and enhance shipbuilding capabilities by updating old production equipment, increasing segmented output, and actively promoting continuous construction of similar ships. At the same time, increase investment in ship design and R&D, and strive to enhance the core competitiveness of the shipbuilding industry. The Korean shipbuilding industry first introduced design drawings from abroad, and produced them under the supervision of foreign classification societies and shipowner technical representatives. Korean companies explored and learned in the production and gradually formed their own independent research and development capabilities. After entering the 1990s, Korean shipping companies began to purposely and systematically introduce LNG ship-related technologies, digest and absorb the technology, and carry out independent innovation based on the imported technology. In recent years, it has taken over LNG ship construction orders in the international market, surpassing China in terms of profitability. Relying on the advantages of the system, China focuses on bulk carriers and container ships, and further maintains its international competitiveness in terms of volume through corporate restructuring and merger.

In addition, the shipbuilding industry is a pollution-intensive industry. Welding, spraying and other processes in the manufacturing process of new ships and the process of ship recycling operations, a large amount of energy consumption and pollutant emissions directly or indirectly damage the ecological environment. The awareness of environmental protection is increasing. The Chinese government attaches great importance to the construction of ecological civilization and environmental protection. It requires that industrial economic development must be coordinated with environmental protection. China's environmental protection policy's zero tolerance for pollution has also sounded environmental protection warnings for the shipbuilding industry. China's shipbuilding industry is also facing the dual pressures of environmental protection and the market. How to maintain competitiveness while strengthening investment in environmental protection is an issue that is closely watched by industry insiders and scholars. The leading technology of the world shipbuilding industry is still in the hands of advanced countries such as Japan and South Korea. At present, the technology intensity of China's shipbuilding industry is still relatively low. China’s ships are very lack of international competitiveness for high value-added ship construction.

Industrial economic theory points out that the growth of the industry comes from the accumulation of factors and the growth of productivity. The guidance of the previous macro policies helped the Chinese shipbuilding industry to quickly achieve the accumulation of factors. The "extensive" growth model, which is mainly based on GDP scale and growth speed, has continuously aggravated environmental pollution, and the contradiction between economic development and environmental protection has become increasingly difficult to reconcile. Policy subsidies have reduced the cost of raw materials, labor prices and land prices to promote the competitiveness of domestic industries in the international market. Although they have achieved remarkable results in the short term, they will inevitably lead to excessive development of resources and ecological damage in the long run. Governments have to strengthen environmental regulations for two reasons. On the one hand, with the deterioration of the global ecological environment, the emergence of environmental problems such as ozone layer destruction, global warming, and extreme climates have sounded the alarm of environmental protection to all human society. The world began to focus on environmental protection. On the other hand, after the financial crisis, in order to save the domestic economy and increase their exports, developed trade protectionists set up higher standards of green trade barriers in the international trade market to restrict imports on the grounds of environmental protection. To continue to maintain the market share of the domestic industry in international competition, it is necessary to strengthen the country's environmental regulations to overcome the green barriers to international trade.

In order to achieve sustainable development and energy saving and emission reduction at the same time, the government actively promotes environmental regulations, but entrepreneurs worry that the negative effects of environmental regulations will damage the development of the industry. The main reasons are: First, the collection of sewage charges increases the number of enterprises operating costs, the decline in profit margins in the short term restricts the expansion of the scale of the industry, and is likely to lose market opportunities; Second, environmental governance investment takes up funds for the purchase of new equipment and research and development of new products, restricting the industry's next round of investment. The impact of environmental regulations on industrial development is also the focus of current debates in academia. The main views are divided into "following cost" theory and "Porter Hypothesis" theory. Although academic researchers and industry decision makers in the industry have launched a large number of corresponding, but still have not reached a unified conclusion.

The Total Factor Productivity (TFP) indicator is an important reference used by the academic community to evaluate the quality of economic growth. It comprehensively measures the sum of all factor contributions and effectively reflects the status of technological efficiency and technological progress. In the study of industrial productivity, the total factor productivity index is widely used to measure the ratio of total output and total input, reflecting changes in factor distribution and utilization efficiency over a certain period. It should be emphasized that productivity growth is a long-term but slow process, which is a continuous driving force for economic growth. Environmental regulation strengthens the process of promoting green transformation of the economy, promoting labor productivity, reducing pollution, reducing energy consumption, and enhancing sustainability. In some extend, it refers to the increase in green total factor productivity. Facing increasingly tight domestic and international environmental regulations, China's shipbuilding industry needs to deal with environmental pollution while improving the quality of development. Measuring green TFP of the shipbuilding industry comprehensively reflects the actual development status. In addition, the evaluation indicators are decomposed into technical progress and technical efficiency, and the main sources of green development of China's shipbuilding industry are analyzed in detail. The convergence analysis aims to explore the balance of the development of the shipbuilding industry in various regions, and systematically expound the development trend of the shipbuilding industry in major coastal cities. In order to further explore the intrinsic decisive power of green total factor productivity in China's shipbuilding industry, the regression analysis of panel datas is delivered in order to focusing on whether environmental regulation has a positive or negative effect on the green total factor productivity of China's shipbuilding industry. At the same time, it analyzes the impact of other factors such as the macroeconomic environment, technological progress, and exports on the green total factor productivity of China's shipbuilding industry.

1.2 RESEARCH STRUCTURE

Based on efficiency theory and economic growth theory, empirical research on the shipbuilding industry is carried out by combining the methods of statistics and econometrics. First, based on the data of 15 shipbuilding provinces and municipalities from 2004 to 2015, the DEA-ML index method was used to calculate the green total factor productivity of China's shipbuilding industry, then decomposed into green technology efficiency and green technology progress indicators. The research on traditional total factor productivity has deeply discussed the development status of green total factor productivity in China's shipbuilding industry; Secondly, using β test to analyze the differences in the growth of green total factor productivity in the three major shipbuilding centers and 15 shipbuilding provinces and municipalities; Then, in order to further explore the determinants of green total factor productivity in China's shipbuilding industry, we selected GDP growth rate, technological progress, export dependence and environmental regulations for dynamic regression analysis. In this step, environmental regulations are the main research variables. Finally, the research is summarized, giving policy implications from aspects such as promoting the transformation and upgrading of the shipbuilding industry, promoting technological progress, developing domestic market demand, and deepening the integration of financial capital and industrial capital, and looking forward to future research. The contents of each chapter are as follows:

Chapter 1 Introduction

This chapter is composed of four subsections, including research background that elaborates the research purpose and research significance of this article. This part also summarizes the theoretical origin and research development of this topic, and finally summarizing the academic contributions and existing deficiencies.

Chapter 2 Chinese shipbuilding industry

This chapter focuses on the shipbuilding industry characteristics and current market circumstance, and elaborate on the definition and characteristics of the shipbuilding industry. By reviewing the development process of the Chinese shipbuilding industry and the world shipbuilding industry from a historical perspective, concisely concludes international market environment and domestic and foreign environmental regulations on the shipbuilding industry. Focusing on the deep-seated problems affecting the operation crisis of China's shipbuilding industry, the main dilemmas faced by China's shipbuilding industry in achieving sustainable development transformation are summarized.

Chapter 3 Literature review

This chapter consists of three parts. First, the concept of green total factor productivity is defined. Secondly, it focuses on the theoretical basis of green total factor productivity. From the early Hicks marginal productivity theory to the "Porter Hypothesis", the theoretical origin and development of green total factor productivity are expounded. In addition, it also summarizes the main methods of green total factor productivity measurement, including parametric and non-parametric methods. Finally, combined with the industry specificity of the shipbuilding industry, a model is established from an empirical perspective to analyze the green total factor productivity of the Chinese shipbuilding industry.

Chapter 4: Measurement and evaluation of green total factor productivity of Chinese shipbuilding

This chapter adopts the data envelopment analysis method, based on the panel data of the major shipbuilding industry regions, and empirically studies the green total factor productivity of the Chinese shipbuilding industry. First of all, the sample selection and main data sources of this study, as well as the selection principles of various indicators, are described in detail. The estimation method of undesired output indicators is described in detail. Then, the collected data is brought into the combination of existing measurement methods. The model measures the green total factor productivity of China's shipbuilding industry, and analyzes the change of the overall green total factor productivity of the Chinese shipbuilding industry from the perspective of the overall development of the industry. From the perspective of regional differences, analyze the total green factor productivity into green technical efficiency and green technical progress. Eventually, the convergence analysis of the differences in the growth of green total factor productivity of the shipbuilding industry is proceed in various regions.

Chapter 5 Determinants of green total factor productivity of Chinese shipbuilding industry

This chapter deeply explored the determinants of green total factor productivity of China's shipbuilding industry, with environmental regulation as the main explanatory variable, and the remaining control variables include the annual growth rate of regional GDP, technological level and the degree of dependence on foreign exports. Separately established static and dynamic regression models for regression analysis to study the intrinsic determinants of green total factor productivity in the shipbuilding industry. In the dynamic model, considering that the previous green total factor productivity and the previous research and development investment will have an impact on the results of the current period, the time lag item will be added to the green total factor productivity and technological progress indicators of the Chinese shipbuilding industry, and finally try to give economic reflection to the empirical results explanation.

Chapter 6 Conclusion and Implication

This chapter summarizes the main conclusions obtained by the empirical analysis. Combining the current status and strategic objectives of the development of China's shipbuilding industry, it gives policies from four aspects: promoting the transformation of the shipbuilding industry, promoting technological progress, developing domestic market demand, and deepening the integration of financial capital and industrial capital. In addition, although this research has contributed to academic innovation, there are still many shortcomings, and these shortcomings will be the direction of future research efforts. Therefore, the prospect section summarizes the main ideas for future research.

Summarizing the logical main route of this study, drawing the technical route of the study is shown in Figure 1-1：

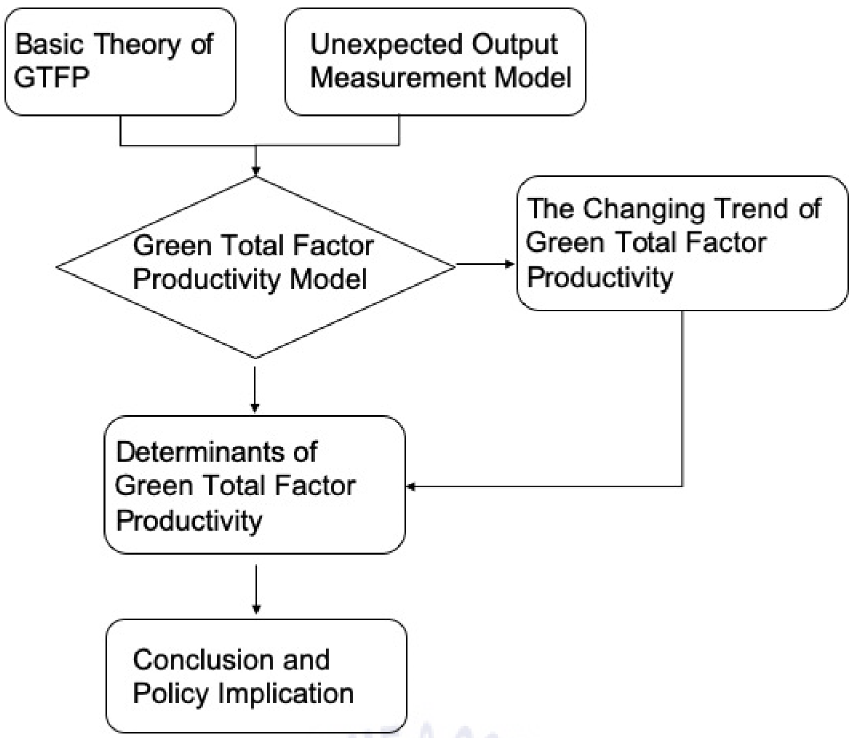


Figure 1- 1 Technical Route

1.3 INNOVATIONS AND DEFICIENCES

1.3.1 INNOVATION

First, consider the evaluation of the green total factor productivity of China's shipbuilding industry in the context of environmental regulations. Based on the characteristics of the shipbuilding industry, energy consumption, labor input, and capital input are used as input elements, ship output as expected output, and pollution emissions as undesired output to build an evaluation model. Compared with the existing models that only consider general input and output indicators to measure total factor productivity, the green total factor productivity evaluation model of China's shipbuilding industry has been innovated.

Secondly, on the basis of the existing research, the difference between the green total factor productivity of China's shipbuilding industry and the traditional total factor productivity after adding resources and environmental factors is compared and analyzed. From the time dimension analysis, it is found that the green total factor productivity of China's shipbuilding industry shows periodic changes. Using the absolute convergence model to test the balance of the development of the shipbuilding industry in various regions, it is found that there is an obvious assimilation phenomenon in the development of the Chinese shipbuilding industry.

Finally, using environmental regulation as the main independent variable, the effect of environmental regulation on the green total factor productivity of China's shipbuilding industry is analyzed. At the same time, the macroeconomic environment, technological progress, and export dependence are taken into consideration, and a comprehensive analysis of the green factor of China's shipbuilding industry Influencing factors. The analysis results show that the tightening of environmental regulations positively promotes the green total factor productivity of China's shipbuilding industry, supports the "Porter Hypothesis" theory, and provides new policy implications for the country's transformation and upgrading of the shipbuilding industry in the new market environment.

1.3.2 DEFICIENCES

First of all, this article focuses on the development of China's shipbuilding industry to externalize other factors in the international market, and the data collection and processing are still insufficient. At present, most of studies that have not yet reached consensus on the selection of environmental regulation indicators, and they are lack of statistics on the emission data of the shipbuilding industry. This paper has estimated the intensity of environmental regulations, but it is inevitable to limit pollution emissions to a few emission indicators, and ignore other pollution problems, and there are still many aspects that need to be improved in dealing with some indicators and variables.

Secondly, this article analyzes the impact on the green total factor productivity of China's shipbuilding industry from the perspective of macroeconomic situation, technological progress, export dependence and environmental regulations. However, in fact, the degree of government participation, foreign investment and capital stock are all affecting the green total factor productivity of the shipbuilding industry. In the future, when studying the impact of environmental regulations on the green total factor productivity of the shipbuilding industry, relevant indicators can be considered more comprehensively.

Finally, the "Statistical Yearbook of Shipbuilding Industry" is the main data source for this study. However, due to differences in statistical content and data availability in different years, it cannot be updated to the latest data, and it does not show the latest changes in green total factor productivity of the Chinese shipbuilding industry.

CHAPTER 2: CHINESE SHIPBUILDING INDUSTRY

The shipbuilding industry is an important strategic industry related to the development of the national economy and national defense security, and it importantly supports for the water transportation and marine development industries. As two important industries of the national economy, they mainly rely on the shipbuilding industry to provide them with equipment. It is a strategic industry in various coastal countries around the world. Observing the development process of the world's shipbuilding industry, Japan, South Korea, Europe and China formed a four-level pattern of the ship market in the last century. In recent years, due to poor cost competitiveness, the European shipbuilding industry has gradually faded out, focusing only on the construction of high-tech and high value-added cruise. At present, the world ship market is mainly occupied by the three East Asian countries. China's shipbuilding industry has always ranked first in the world due to its comprehensive advantages.

2.1 SHIPBUILDING GROWTH AND TRENDS

After World War II, the world began to invest in industrial development and economic construction. The World Shipbuilding Center moved from Britain to European countries and then to East Asian countries (see Table 2-1). Japan has overtaken the United Kingdom as the world's first shipbuilding country since 1955. Its shipbuilding Technology is still at the highest level in the world. South Korea closely followed Japan's vigorous development of the domestic shipbuilding industry, and surpassed Japan in ship orders for the first time in 1990. Prior to the financial crisis, the status of the world's number one shipbuilding power has been controlled by South Korea. After the reform and opening up, the Chinese government focused on the development of heavy industry and positioned the shipbuilding industry as a national strategic industry. As part of China's industrial expansion, the large-scale expansion of China's shipbuilding capacity accelerated in the late 1990s.

Table 2- 2 Merchant ships completed during years, 1960-2015('000 GT)

	1960	1970	1980	1990	2000	2005	2010	2015
Asia								
Japan	1839	11708	6094	6663	12020	16100	20198	12877
South Korea	--	562	522	3441	12228	15400	32202	23751
China	--	110	--	404	1647	5700	38186	25260
Taiwan	--	196	240	685	603	500	574	724
Singapore	--			49	17		133	41
Far East	1839	12576	6856	11242	26515	37700	302	131
Rate	22%	46%	52%	70%	84%	85%	86%	90%
Europe	5565	11230	3336	2945	3402	4400	1258	80
Rate	66%	41%	25%	18%	11%	10%	1%	-
Eastern Europe	393	1760	1347	1300	1154	1300	-	-
Rate	5%	6%	10%	8%	4%	3%	-	-

Other	965	1965	1562	1047	626	1044	57	27
Rate	12%	7%	12%	6%	2%	2%	-	-
The World	8382	27531	13101	18156	31696	44444	98562	37170

Source: Lloyd's shipping database, Clarkson World Shipbuilding Monitoring

Since the 1960s, the Japanese manufacturing industry has implemented on-time production. Through the compression of equipment investment, efficient and reasonable management and technological innovation, the shipbuilding industry has reduced equipment investment by half in this context, and a large number of personnel have been streamlined to maintain high efficiency. For nearly half a century, Japan has relied on high-complexity shipbuilding orders on the international market to maintain its leading position in world shipbuilding technology. In recent years, Japan has been secretly working on unmanned ships and smart ships. A large amount of capital has been injected into the research and development of ship types, the development of new projects and the purchase of new production equipment, in order to seize the market opportunities during the period of demand changes in the ship market Shape the core position of the Japanese shipbuilding industry. The development of the Korean shipbuilding industry is relatively early, and the shipbuilding technology level and management system are relatively mature. South Korea mainly produces high value-added ship types depending on its advanced technology level. Especially before the financial crisis, although the global shipbuilding industry fluctuated slightly, the ship market was still developing at a high speed. During this period, the South Korean shipbuilding industry relied on domestic government support, and the level of development was also constantly improving. In the early stage of development, my country's shipbuilding enterprises quickly adapted to market changes by taking advantage of the institutional system, accelerating the pace of adjusting structure and changing methods, and seizing the market boom period to improve its competitive position in the international market. Subsequently, the shipbuilding indicators of China and South Korea have been leading the rest of the world, occupying a total of about 90% of the market. The impact of the financial crisis and the European debt crisis has created a situation of dislocation competition between the shipping industries of the two countries. China is here to take advantage of the system to expand orders in the international market through continuous consolidation and expansion. In 2009, China's shipbuilding orders surpassed South Korea and became the world's first shipbuilding country.

Like many other industries, the cycle of prosperity and depression is a basic feature of the shipbuilding industry. A large number of macro and public financial research literature discusses the best fiscal policy in the entire economic cycle, and usually recommends the use of counter-cyclical fiscal policy, with a view to smoothing inter-period consumption, reducing the efficiency cost of economic cycle fluctuations, and increasing by reducing volatility Long-term investment(Aghion P, Dewatripont M, Du L, & al.; Barro, 1979; Gali J, Gertler M, Lopezsalido D, & al., 2002). The periodicity of the development of the shipbuilding industry is mainly affected by the marine economic cycle. Stopford observes the world shipbuilding data, dividing the two types of cycle from prosperity to recession and recession to prosperity on the time axis. The average cycle lasts 9.6 years, the shortest cycle is only 5 years, and the longest cycle is up to 25 years(Stopford).

From the boom to the trough, the average duration of the cycle is 3 years, and the average output reduction is 52%. The most recent cycle was after the 2008 financial crisis. The world's shipbuilding industry began to decline from a total output of 61 million grt during the boom period. Although there have been signs of recovery in the past two years, industry experts pointed out that it is still in a market recession. From cyclical decline to prosperity, the average duration of the cycle is 6 years, and the average increase in output is 322%. Empirically, the development cycle of the shipbuilding industry is an economic cycle of rapid decline and slow prosperity. From the last boom period to the next boom period, the average duration of the cycle is 9.6 years. These cycles are not random fluctuations, but are part of a mechanism to adjust shipbuilding capabilities to meet the needs of world trade.

As the expansion of Asia and China brought about a recovery in trade, the world's shipping industry has undergone dramatic changes. The essence of the ship market is so volatile is that the market uses price volatility to balance the supply and demand of ships, while attracting high-cost manufacturers and eliminating low-cost manufacturers. The ship market is one of the most open and competitive in the world. Behind the economic cycle phenomenon is the essence of price mechanism control. Ship transaction price fluctuations and the huge amount of funds involved, and the production of ships is usually order-based production, making market transactions very tricky, and shipyards must be very keen on price strategies. For example, in the market cycle of rising prices, shipyards and shipowners take greater risks when signing orders, but find that when the ship is delivered, the price doubles and the cost also increases. For example, some VLCCs signed a contract at a price of US$70 million in 2003, but they have appreciated to US$126 million when they were delivered in 2006. The ship market price index is shown in Figure 2-1.

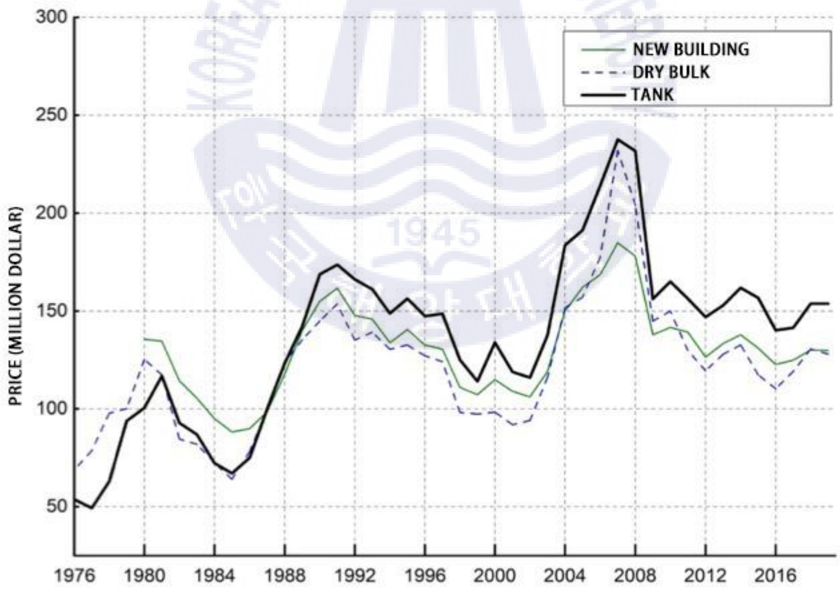


Figure 2- 3 Price Index

Resource：Clarkson SIN

The growth of the world economy and trade has slowed, and the demand for new ships has declined. Observing the trend of changes in world ship prices, the current ship market is sluggish, and prices have been declining since the 2008 crisis. Observe that in recent years, the price index of dry bulk newbuilding is lower than the comprehensive price index of newbuilding. my country's shipbuilding industry has always focused on dry bulk ships, and its profit margin has narrowed as the price of dry bulk ships in the world has decreased. The deep-seated problems such as difficulty in employment, difficulty in financing and difficulty in receiving orders have not been fundamentally resolved, and the situation facing the shipbuilding industry is still grim. In contrast, the new shipbuilding price index for oil tankers is significantly higher than the dry bulk new shipbuilding price index, and shipbuilding developed countries such as Japan and South Korea are clearly competitive in terms of profitability.

2.2 CHINESE SHIPBUILDING DEVELOPMENT

China has a very long history of shipbuilding. In addition to its vast land territory, it is also a country with a wide sea area. It stretches from the Yalu River Estuary in the north to the Beilun River Estuary in the south. The coastline of 18,000 kilometers provides China's superior natural navigation surroundings. From the invention of the canoe to the creation of the giant sea boat, it shows that China has its own independence and creativity in the shipbuilding industry, and has occupied a leading position in the world for a long time in the past. During the Song Dynasty, the ship technology was very mature. A ship was divided into 13 cabins with 12 bulkhead cabins, and an outer keel shape with particularly high structural strength appeared. The pinnacle of ancient ship technology development was the Ming Dynasty, and Zheng Hebao Ship was the world's premier giant ship at that time. With a length of 63.25 meters, a width of 13.8 meters, 6 masts and 8 sails, and a displacement of about 1300 tons, this was the only seven feats of sailing to the west. However, after the outbreak of the Industrial Revolution, the British aggression military armored warships opened the door of China's feudalism and closed the country, letting the Chinese clearly realize that compared with the advanced countries of the world, China's shipbuilding technology is so backward that it has to buy advanced ships from developed countries.

After the reform and opening up, China took the lead in developing the shipbuilding industry and entering the international market. In 1995, with a market share of 5%, it surpassed Germany for the first time in terms of shipbuilding indicators and became the third largest shipbuilding country in the world, second only to Japan and South Korea. In 1999, under the guidance of national policies, the resources of the shipbuilding industry were reintegrated, and China Shipbuilding Industry Corporation (CSSC) and China Shipbuilding Industry Corporation (CSIC) were established. In 2010, my country's shipbuilding industry's new orders accounted for more than 60% of the world's total. The three major shipbuilding indicators exceeded South Korea for the first time, ranking first in the world, and reconstructed the world shipbuilding pattern. At present, China's shipbuilding industry is huge, and it is already in a leading position in the global market. Observing the international trade market, my country imports a large amount of energy and raw materials from other countries in the world, and also exports its own raw materials and products to other countries. The expanding import and export trade has led to the prosperity of the world's shipping economy. In recent years, China has imported a large amount of raw materials such as iron ore, occupying half of the dry bulk cargo flow by sea. The shipping industry provides transportation and also provides technical support for national defense construction and national defense security.

Under the background of the new era, the shortcomings of high pollution and high energy consumption of the traditional shipbuilding industry are gradually revealed, and it is imperative to transform and upgrade the shipbuilding industry. The main participants in the shipbuilding industry are shipbuilding enterprises, and shipowners are the source of ship orders. The design and development of ship types also involve engineers and ship inspection agencies. In order to allow ships to pass through the world's waters smoothly after construction, they need to meet Regulations and specifications proposed by relevant organizations in the world. For example, the current strict global environmental regulations have made green innovation the core of the shipbuilding industry, achieving the sustainable and ecological development of the shipbuilding industry, thereby achieving the goals of saving resources and protecting the environment. In addition to the shipbuilding industry's main responsibility for the quality and safety of shipbuilding products, classification societies and shipowner representatives are also responsible for the supervision and management of the quality of shipbuilding products, and put forward new requirements for shipbuilding in light of the development situation of the industry. However, my country's shipbuilding industry itself has special characteristics that are different from other countries. Green innovation has the characteristics of high risk and uncertainty of innovation results. Multi-party participation in cooperation in green innovation communication can reduce risks and improve efficiency.

Taking the lead in achieving green innovation can enable the shipbuilding industry to obtain excess profits, seize market opportunities, and achieve competitive advantage. Under the common appeal of the shipping industry and shipbuilding industry for green and environmentally friendly products, both upstream and downstream enterprise participants centering on shipbuilding need to increase the research and development of key core technologies and strengthen cost control and management.

2.3 CHINESE SHIPBUILDING KEY CHARACTERISTICS

China's shipbuilding industry occupies a relatively high international market share in terms of total volume and has strong competitiveness. A large number of factor inputs and scale expansion have promoted China to become a major shipbuilding country in the world, but it has also brought obvious side effects, restricting the strengthening of the shipbuilding industry, the dependence of core technologies on imports, the uneven development of supporting industries, and insufficient demand. bottleneck. In addition, the maritime market continues to be sluggish, the reduction of orders in the international market, and difficulties in financing have caused some shipping companies to have a large amount of excess capacity and profitability. At the same time, environmentalism puts the focus on the shipping industry. Ships need to follow the corresponding environmental regulations from design to production and later navigation. Faced with the double predicament of market and environmental regulation, the main problems revealed by the shipbuilding industry are as follows.

2.3.1 OVERCAPACITY

During the prosperous period of shipping, China's shipbuilding industry accelerated its industrial expansion to obtain orders in the international market. However, the unexpected arrival of the financial crisis, coupled with the rise of international trade protectionism, the uncertainty of the international trade environment has reduced the demand for dry bulk carriers and container ships. When the world shipbuilding industry is undergoing periodic adjustments, the world's financial institutions adopt a "one size fits all" approach to the financing of shipbuilding enterprises, resulting in some domestic key shipping companies with good operating conditions and international competitiveness failing to obtain timely funds and failing to receive orders Difficulties. There is still a gap in the industry-finance integration work in the shipping industry, which does not fully reflect the implementation of the differentiated credit policy of support and control by the Central Economic Work Conference.

Observing my country's three major shipbuilding indicators (Figure 2- 2), the shipbuilding indicators of the Chinese shipbuilding industry have continued to decline after 2014, and the market is not optimistic.

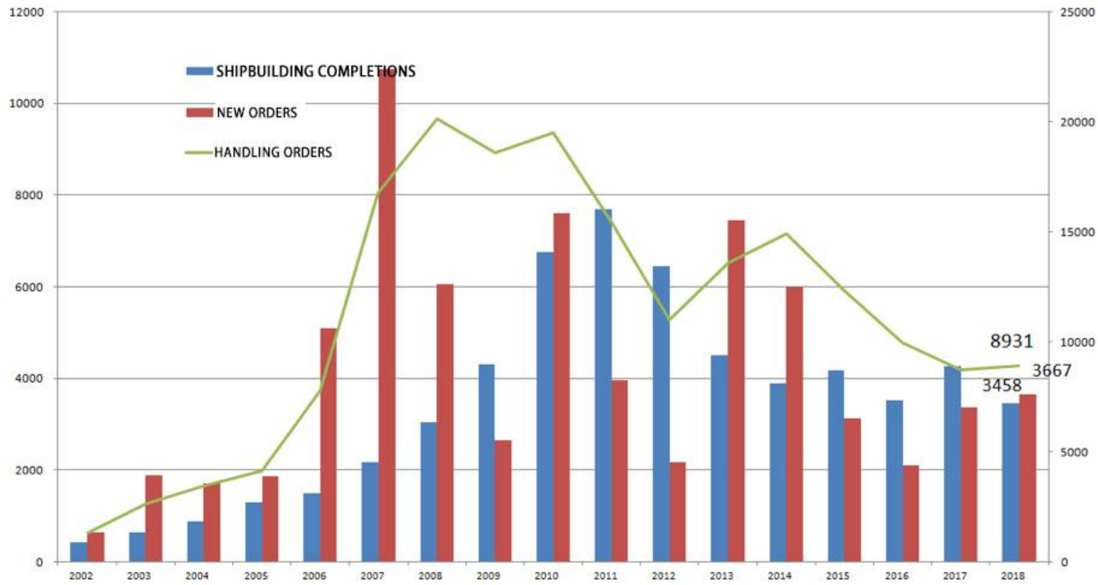


Figure 2- 4 China’s Shipbuilding Index

Source: China Shipbuilding Industry Association

Although policies such as supply-side reforms implemented in China have structurally adjusted the development of my country's shipbuilding industry, and have played a role in promoting the transformation and upgrading of my country's shipbuilding industry. However, the price of new ships is decreasing in the downward market. Since the agreed price of hand-held orders is higher than the market price, shipowners often take measures to postpone payment, postpone delivery, and even "abandon the ship." The common phenomena of “difficult to receive orders”, “difficult to deliver” and “difficult to finance” make it difficult for the shipyard to continue production.

In addition, the global new ship order structure has evolved from the traditional three mainstream ship types to the five mainstream ship types, and the demand for LNG ships and luxury cruise ships has increased significantly. South Korea's shipbuilding industry has won all the world's LNG ship construction orders in 2019 with its advanced production technology in the field of LNG ship types. Such high value-added ship construction has brought greater room for profit for the Korean shipbuilding industry. According to calculations, the international market share of China's shipbuilding industry tends to widen. The ship types that can be built are relatively limited and the dry bulk ship market demand is reduced, which makes it difficult to penetrate other ship types markets and exacerbates the problems of overcapacity and insufficient construction.

2.3.2 WEAK INNOVATION

The development of China's shipbuilding industry started late, and it entered the market in the form of a large amount of labor and capital input. Its own technology precipitation is not enough, and the core technology is still in the hands of shipbuilding companies in developed countries. In the early stage of development, considering the low risk of innovation, China's shipbuilding industry has followed the path of imitating innovation. By observing the innovative behavior of the international shipbuilding industry, it has learned from many technological pioneers and introduced the most successful technologies to absorb, Digest and improve. The imitation innovation model puts limited technical power and funds into the design, craftsmanship, production and manufacturing of ships, which has greatly improved the development of my country's shipbuilding industry in the early stage. Later, through cooperation with shipbuilding companies in Germany, Japan and South Korea, a cooperative innovation model was formed, relying on the development strategy of the country's advanced technology level of the shipbuilding industry "high investment, high technology and high goal" to realize part of the technology in the form of cooperation Sharing. Due to the lack of independent innovation capabilities, it can only focus on the manufacture of low value-added and technology-intensive dry bulk ships and container ships.

However, in the context of my country's economic and world trade development, exemplary innovation and cooperative innovation with a certain lag will restrict my country's development goals as a world shipbuilding power. Considering that the technology of the shipbuilding industry is not only required by civilian ships, but also the center of gravity of national defense construction. Really high, sophisticated, and sophisticated technologies are difficult to obtain in the international market and must rely on the independent innovation of the country. Moreover, independent innovation technology often has high technical barriers, and countries with independent innovation technology can often obtain monopoly profits. At present, my country's shipbuilding industry lacks independent innovation capabilities, which is mainly manifested in the inconsistency of scientific research and industrial development, and the low achievements in the transformation of production, education and research. The lack of technological innovation capabilities has led the Chinese shipbuilding industry to focus on coping with production tasks. The production model has always been in a passive situation. By taking orders before starting design, or even designing during the production process, there is a lack of initiative and reserves to develop new ship types technology. The shipbuilding industry technology involves the main technology and related technologies, such as high-efficiency welding and precision control. The ship building process is the main technology, which directly affects the construction level. Related technologies are mainly reflected in the innovation of production equipment and workpieces, and the innovation of production line management models. Among them, the main innovation carried out by the ship production process is the basis of product innovation. It is only emphasized that product innovation is difficult to maintain economic growth. At present, neighboring developing countries such as the Philippines and Vietnam are beginning to enter the international shipbuilding industry market with lower raw materials and labor. The traditional development model of the Chinese shipbuilding industry is obviously not adapting to the new international competition landscape. Strengthening ship design and research and development of new technologies can enhance the profitability of the shipbuilding industry and enhance the sustainability and competitiveness of the shipbuilding industry.

2.3.3 SHIPBUILDING SUPPORTING LAGS BEHIND

The backward development of the shipbuilding industry is a key factor restricting the development of China's shipbuilding industry. The performance appraisal method aimed at orders and production has made China's attention to the field of marine equipment very scarce. Foreign manufacturers import marine supporting products, and the import penetration rate of core components is high. Lack of corresponding industrial policy guidance and support, domestic marine equipment products are not recognized in the international market, and foreign technicians cannot perform maintenance and other problems, and can only be used for the construction of inland ships. According to statistics, the equipment used in the Japanese shipbuilding industry almost uses Japanese domestic suppliers, and the localization rate reaches 98%-100%. South Korea also has a localization rate of more than 90% in this indicator. The conversion rate is less than 40%.

At present, relevant international organizations continue to issue new regulations on the upgrading of ship products. The operation of the fleet is restricted by more and more regulations. The international shipowners are increasingly demanding green and environmentally friendly, safe and reliable, intelligently optimized ships and supporting products. The rate of upgrading of marine products has accelerated. With the complication of international multilateral relations, Japan, South Korea and the EU countries have strengthened the blockade of their own advanced technologies. Many Chinese shipyards have been unable to purchase parts from other countries and played the role of "assembly plant", which is at a disadvantage. China's shipbuilding industry is facing severe challenges.

2.3.4 LACK OF INNOVATION TALENTS

The direct creators of corporate profits depend on senior technical personnel. Although China's shipbuilding industry has the advantage of low labor costs, the overall quality of labor is low. There is a big gap in innovation talents in the shipbuilding industry. According to statistics, the number of innovation talents in China's shipbuilding industry was only 1.02 million in 2015. There is a shortage of innovative leading talents and "big country craftsmen". The stereotype of the shipbuilding industry has made a new generation of young people unwilling to enter the shipbuilding industry due to poor shipyard operating environments, high risk factors, and high skill requirements. If young people are unwilling to dig deeper and faults occur for generations, the future of the shipbuilding industry is worrying.

At the same time, the benefits of shipping companies have declined significantly compared to before the international financial crisis, and the loss of university graduates and senior ship professionals and skilled technicians is severe. According to relevant statistics, the labor costs of shipping companies have increased 5% to 10% annually, which is much higher than the improvement of the production efficiency of shipping companies, which has brought huge cost pressure to shipping companies that are already in a small profit or even a loss. At present, China's shipbuilding industry has entered a period of in-depth adjustment and a period of restructuring of advantages. Difficulties in employment, expensive labor, and a shortage of innovative talents have drawn great attention from all quarters. These problems reflect my country's weak support for the introduction, cultivation policies and investment of senior talents in the shipbuilding industry, and the lack of a diversified incentive mechanism. A one-sided evaluation system that focuses on the number of papers and scientific research projects makes the development of scientific research personnel disconnected from the market and engineering application needs. The growth path of innovative talents is single, the lack of a long-term effective guidance mechanism, the low status of senior talents in the shipbuilding industry and the low income of skilled talents have weakened the enthusiasm of scientific and technological talents and skilled personnel to engage in technological innovation, and led to the ultimate Brain drain.

2.3.5 FACTOR INTENSITY

Early shipbuilding mainly relied on a large amount of labor input. With the increase in labor costs in Europe and the United States, it was transferred to East Asia. Whether low labor input was the main focus of the development of the shipbuilding industry. However, the maritime economic cycle of the last century brought about a great depression in the shipbuilding industry. The shipbuilding industries of various countries have purchased new production technologies and equipment in the midst of difficulties. And capital-intensive. In 1960, the number of laborers per 10,000 ton of major Japanese shipbuilding companies was 699, and by 1995 the data had dropped significantly, requiring only 47 people per 10,000 ton of ship construction. From the perspective of development history, Japan's shipbuilding industry was the first to show a significant decrease in labor intensity, and the Korean shipbuilding industry also followed by a substantial reduction in manpower input. China's shipbuilding industry started late, lacking advanced production technology and efficient management models, and the labor intensity is still significantly larger than that of developed countries.

With the rapid development of ship technology in the world today, shipowners in the world have stricter requirements on technology and quality, and competitors Japan and South Korea have increasingly increased technological innovation. The Chinese shipbuilding industry is facing huge challenges. Increase investment in research and development, improve innovation capabilities, strive to develop green and environmentally friendly ships that meet market needs, build branded ship models, and lead the market with technology.

CHAPTER 3: LITERATURE REVIEW

The direct source of green total factor productivity theory is total factor productivity, but its theoretical basis can be traced back to economic growth theory. This chapter first summarizes the theory of green total factor productivity, then summarizes the two main points of environmental regulation and related research on the shipbuilding industry, and reviews objectively the results and shortcomings of existing research.

3.1 TOTAL FACTOR PRODUCTIVITY

The prerequisite for an economy to operate effectively is the optimal use of all resources. Whether the use of resources is optimal requires attention to efficiency indicators, and the significance of efficiency is mainly to focus on the degree of conversion between input and output. In an ideal state, all resources are most efficiently allocated, and the optimal economic benefit is the Pareto optimal in economics. Further, Samuelson's definition of the best efficiency state without waste requires that there is no unnecessary increase in raw materials in product production. The well-known American economist Solow believes that efficiency reflects technological progress, and for the first time proposed the "Solo residual value" method under the premise of assuming Cobb Douglas (C-D) production function(Solow, 1957).

The level of technological innovation in a certain period of time in an economy and the efficiency of factor distribution collectively reflect the utilization of production factors and the level of productivity. According to the specific research, whether to consider a single factor or multiple factors is divided into single factor productivity and total factor productivity. Single factor productivity only considers a single input such as labor productivity, which is the ratio of output to labor input. In the actual production process, factor inputs include many factors such as labor, capital, and resources. Domestic scholar Chen Shiyi proposed in the study of economic growth that, in addition to the growth brought by input factors, technological progress and efficiency improvement also brought part of economic growth, which reflected the quality of economic growth and was determined by total factor productivity Said. Technological innovation and efficiency improvement together form the total factor productivity, which includes pure technology efficiency improvement and scale efficiency improvement. The accumulation of new knowledge and new technologies is the essence of technological innovation and the source of productivity. Pure technical efficiency refers to the increase in efficiency brought about by management experience and institutional innovation. Operation will bring corresponding economic benefits.

In the academic research on the quality of economic growth and the internal structure of the industry, the core indicator selected is total factor productivity. Since the solo residual value method was proposed, the ambiguity of input factors in production and the lack of production function variables have become the subjects of more and more scholars. Many research results have gradually enriched and improved the evaluation system of total factor productivity. The evaluation methods of total factor productivity include parameter method and non-parameter method. The parameter method is divided into CD function method, algebraic index method and transcendental logarithm method according to different production functions.

The above three methods assume the production function form and grasp the input and production. Analyze the price. The non-parametric analysis method is widely used in the actual production field. The data envelopment analysis method (DEA) is used as the representative non-parametric analysis method to construct the production frontier from the input and output of the decision unit, which effectively avoids the model construction differences, random disturbances and normal distribution error caused by the equal-strength assumption also allows the existence of multiple outputs without considering the existence of inefficiencies. Therefore, it is favored by researchers.

3.2 GREEN TOTAL FACTOR PRODUCTIVITY

The rapid advancement of the world's industrialization process has brought about outstanding environmental pollution problems while meeting people's more material needs. The deteriorating ecological environment has begun to pose unprecedented challenges to human survival and development. It is worth noting that the imbalance of economic development is common in all countries in the world. The earliest development in developed countries also tasted the bitter fruits of environmental pollution and called the importance of environmental protection in the international community. In addition, relying on its dominant position in international trade to transfer pollution-intensive industries to developing countries with lower environmental standards, the "Pollution Refuge Hypothesis" was proposed (Copeland & Taylor., 2003).

The developing countries are forced to choose the development strategy of first development and then governance due to lack of accumulation of their own capital and technology. Therefore, there is a "Matthew effect" in world ecological protection. In the 2018 Global Environmental Performance Index (EPI) report, China ranked 177, only ahead of India, Bangladesh and Nepal. Among the 100 most polluted cities published in the Global Air Quality Report, 57 cities in China were selected. Although the pollution level has declined compared to the past, it still reflects the poor air quality in China. In addition, China is also the country with the most severe damage to biodiversity, and sea pollution is very obvious (Mohtadi, 1996) and Ramanathan et.al. (Ramanathan, 2005).

3.2.1 THE DEFINITION OF GREEN TOTAL FACTOR PRODUCTIVITY

Throughout the history of economics development, the exploration of the source of economic growth has formed rich productivity theories in different periods. Labor productivity and capital productivity in classical economics are the origins of single factor productivity. However, the production process in practice often requires the input of multiple factors, and economic growth is increasingly dependent on technological progress. The economist Tinbergen added the time trend to the CD production function, and for the first time proposed multi-factor productivity, which comprehensively reflected the effective utilization of factors in the production process, and the level of technological innovation, input allocation efficiency, and production management level of the economic system in a certain period Etc. are important concepts in contemporary economic theory. Subsequently, Solow introduced on the basis of the "Solow residual value" constructed by the assumptions of technology neutrality and constant returns, defining growth other than capital and labor input as technological progress, and promoting the development of total factor productivity (Tiebout, 1956).

However, based on input and output in the traditional sense, studying total factor productivity through exogenous resources and environmental factors tends to overestimate productivity. At present, environmental problems are intensifying day by day, and resource depletion and pollution emissions have become rigid constraints on economic development. The traditional total factor productivity analysis that exogenies energy input and pollution emissions is flawed and deviates from the guidance of industrial policies. Scholars began to study the technical efficiency and total factor productivity in the production process in consideration of environmental factors, and continuously expanded the theory of green total factor productivity. Chung & Färe (Y. Chung & Färe, 1995) established a total factor productivity model of undesired output is established, and pollution emission is used as the undesired output, which provides new ideas for the research of green total factor productivity.

3.2.2 THE THEORY GREEN TOTAL FACTOR PRODUCTIVITY

If a policy can stimulate technological innovation, industrial productivity can be improved. The theory behind this view can be traced back to Hicks' marginal factor theory, that is, increasing factor costs will stimulate innovation, thereby reducing the input of this factor (Shove & Hicks, 1933). In the simplified production function, environmental regulation will have a negative impact on the traditional factor marginal productivity (MFP). This point of view pushed researchers to consider pollution or broader environmental issues as missing inputs or missing outputs, and developed green MFP calculations.

With the deepening of the concept of sustainable development of the global economy and the increasingly strict environmental regulations, the theory and empirical analysis of green total factor productivity formed by introducing resources and environmental indicators into the traditional total factor productivity model is constantly emerging. The theoretical support of green total factor productivity is mainly the combination of total factor productivity theory and environmental economic theory. The development of total factor productivity theory has achieved fruitful results in theoretical analysis and empirical research. In contrast, the environmental economic theory still has different views, and because of the limitations of data and problem identification, most empirical studies start from the meso-industry or micro-enterprise level, and come to different conclusions (Kozluk & Zipperer, 2015). The corresponding theoretical and empirical research has been carried out from the micro-enterprise level, the meso-level industry level and even the macro-level country level. The main researchers at the enterprise level include Gray (Gray, Shadbegian, & Ronald, 2003)、 (Becker, 2011) 、(Fan, Zivin, Kou, Liu, & Wang). Berg et.al. (Berg, Forsund, & Jansen, 1992) studied the total factor productivity growth of the Norwegian Bank during the policy relaxation period and the selection of multiple output variables illustrate the change in productivity growth rate over time.

Research on the meso-industry level includes Domazlicky (Domazlicky & Weber, 2004), which take the American chemical industry as the research object. Research at the macro level is relatively scarce. Jeon et al. (Jeon & Sickles, 2004) studied the impact of carbon dioxide emissions and other greenhouse gas emissions on overall economic efficiency, and believed that environmental regulation reduced the factor marginal productivity of the economy. Taken together, the green total factor productivity theory proposed by scholars still lacks a systematic and comprehensive research framework.

Academia generally believes that resources and energy factors are the main sources of negative environmental externalities, but there is still a lot of controversy about the selection and treatment of specific environmental indicators. Some scholars recommend environmental factors as input elements.

While another part of scholars believe that it is more reasonable to treat environmental destruction as undesirable output. In the current study, the main indicators used are shown in Table 3-1.

Table 3- 2 Indicators involved in empirical research

Dependent variable	Independent variable	Sample	Author and Year
ΔTFP	Effective implementation ratio of statutory emission targets	American Power Industry 1973-1979	(Gollop & Roberts, 1983)
ΔTFP	Payment of biological oxygen demand and suspended solids emissions	Canadian Wine Industry 1971-1980	(Smith & Sims, 1985)
TFP	Number of local environmental regulations	American Petroleum Refinery 1977-1992	(Berman & Bui, 1998)
TFP	PAOC	American Pulp Mill 1979-1990	(Gray et al., 2003)
TFP	Whether it meets air pollution regulations	American Manufacturing 1972-1993	(Greenstone, List, Syverson, & al, 2012)
ΔTFP	Governance investment	5 U.S. manufacturing industries 1960-1980	(Barbera & Mcconnell, 1990)
TFP	Induce R&D investment	5 Japanese manufacturing 1966-1982	(Hamamoto, 2006)
TFP	R&D investment induced by environmental regulations	Taiwan Manufacturing 1997-2003	(Yang, Tseng, Chen, & al, 2012)

Some early scholars incorporated resource and environmental factors as input variables into the total factor productivity model, Reihard et al.(Reinhard, Lovell, Thijssen, & al, 2000) analyzed the comprehensive environmental efficiency of Dutch dairy farms, established the minimum feasible ratio of multiple harmful inputs as environmental variables, and established DEA and SFA models for research. Because environmental resources are difficult to price in the market, introducing productivity models directly as input variables distorts the actual input-output relationship. Chung et al. (Y. H. Chung, Färe, & Grosskopf, 1997) used the directional distance function and the treatment of pollution emissions to construct a DEA evaluation framework with undesirable output. The green total factor productivity developed from this was widely adopted by subsequent researchers.

3.3 ENVIRONMENTAL REGULATION AND CHINESE SHIPBUILDING INDUSTRY

Marshall, the pioneer of the neoclassical economy, first proposed the concept of externality. His student Pigou further distinguished between positive and negative externalities, and conducted an original analysis of public products with externalities, pointing out that one cannot rely on "invisible hands." "To eliminate externalities (A.C.Pigou, 1999; Marshall, 1890). However, the provision of public goods by the government needs to satisfy the value of the public goods equal to the total willingness of all users to pay, which is the famous Samuelson criterion (Samuelson & Paul, 1954).

Externality is independent of the market mechanism and is a typical performance of market failure. Bator (Bator, 1958) built a general equilibrium model that includes externality to correct the market equilibrium point. The negative externalities of the environment determine that environmental regulation is currently the main means for overall economic sustainable development. In theory, there is a close relationship between environmental pollution, governance investment, and economic development (Grossman & Krueger, 1991). The research on the economic effects of environmental regulation is mainly divided into two schools. The "following cost" school believes that the implementation of environmental regulation mainly harms economic development from two angles. First, restricting the use of natural resources has promoted the increase in factor prices and production costs. Increase weaken the market competitiveness of enterprises. Secondly, inevitably increasing pollution control costs, introducing advanced green technologies and improving the original production process, squeezing out limited capital investment, is a negative effect on economic efficiency. Gollop et al. (Gollop & Roberts, 1983) calculated the impact of environmental regulations on the US fossil fuel power generation industry from 1973 to 1979. The conclusions show that environmental regulations bring significantly higher power generation costs and the average annual productivity decline is 0.59%. Gray et al. (Gray, 1987) analyzed the manufacturing industry in the United States and concluded that environmental regulations have impaired the growth of average manufacturing productivity. Jargenson et al. (Jorgenson & Wilcoxen, 1990) analyzed the impact of environmental regulations on the GNP of the United States from 1973 to 1985, and believed that environmental regulations brought higher operating costs and inhibited investment in the long run, thereby damaging long-term economic growth. Barbera et al. (Barbera & Mcconnell, 1990) divided the impact of environmental regulation on total factor productivity of the industry into direct and indirect effects. Empirical analysis of different industries has shown that pollution control has led to a significant reduction in total factor productivity.

The representative of the cost compliance, Jaffe et al. (Jaffe & Palmer, 1996), used panel data from the US manufacturing industry to analyze the effect of environmental regulation on technological innovation. The conclusion shows that the strengthening of environmental regulation has indeed stimulated investment in R&D funds, but it is not statistically related to changes in total patent results. Ederington et al. (Ederington & Minier, 2003) internalized environmental regulations into the international trade model for empirical analysis. The results suggest that environmental regulations have formed trade protection barriers in international trade and restricted the country's foreign imports. Christainsen (Christainsen & Haveman, 1981)and others studied the impact of environmental regulations on the economic downturn and pointed out that the cost of compliance with environmental regulations accounts for the company's investment costs for future projects.

Contrary to the above view, the "Porter Hypothesis" represented by Porter(Porter & Claas, 1995)、Berman(Berman & Bui, 1998)、Ambec et al.(Ambec, Cohen, Elgie, & Lanoie, 2013) believe that environmental regulations encourage enterprises to change their original production schemes, reduce redundant inputs, and optimize production efficiency. The resulting reduction will hurt competitiveness, but in the long term, the "compensation effect" of innovation triggered by environmental regulation will compensate for compliance costs. A large number of scholars carried out research to test and obtained many supporters. Rubashkina (Rubashkina, Galeotti, & Verdolini, 2015) used European manufacturing panel data for empirical analysis, and concluded that environmental regulations have a positive effect on innovation activities that use patents as proxy variables, and verified the Porter hypothesis. Khanna et al. (Khanna & Damon, 1999) studied the motivation of environmental protection participation and its impact on the toxic emissions and economic performance of American Chemical Industry Corporation, and found that following environmental regulations has a statistically significant negative impact on the company's current return on investment, but on the company's expected The impact of long-term profitability is positive and statistically significant.

The research on the productivity of the shipbuilding industry in foreign academic circles mainly focuses on the selection of indicators, and the research direction mainly focuses on the discussion of a specific ship market competitiveness. Chinese scholars' research on the economic level of the shipbuilding industry mainly focuses on the study of productivity. The research objects can be divided into two aspects: industry-based technical efficiency and industrial structure research.

In summary, there are three main shortcomings in the current research: First, there are relatively few academic researches on the productivity and international competitiveness of the shipbuilding industry. DEA production frontier, the results are incomparable in multiple periods; second, in terms of the impact of environmental regulations on the green factors of the shipbuilding industry, qualitative analysis is mostly lack of quantitative research; third, the existing literature focuses on static regression analysis research needs to be deepened.

CHAPTER 4: MEASUREMENT AND EVALUATION OF GREEN TOTAL FACTOR PRODUCTIVITY OF CHINESE SHIPBUILDING

Theoretical analysis shows that China's shipbuilding industry is still in low-quality "extensive" growth, and the traditional growth model has exposed problems such as overcapacity, insufficient innovation and unsustainability under the impact of the marine market cycle. Moreover, the original raw material and labor cost advantages are gradually disappearing, and international competition is becoming more complex and deepening. At the same time, the awareness of environmental protection at home and abroad has increased, the pollution problems caused by shipbuilding have become increasingly serious, and investment in pollution control has increased in the cost of ship construction. The profit margin of ships is further reduced, and the development of the shipbuilding industry in fierce competition must take a sustainable development path. To reposition the development of China's shipbuilding industry, we cannot just hover at the low end of the industry chain, focus on the green and environmentally friendly and technology-intensive ship market, and move towards the high-end ship market on the basis of maintaining the volume.

This chapter introduces pollution emissions into the total factor productivity model, selects the DEA analysis method and the ML index to measure the green total factor productivity of China's shipbuilding industry. Expected output and unintended output. Then, it analyzes the change of the green total factor productivity index, and analyzes the change trend of the green total factor productivity of the national shipbuilding industry over time and the change trend of the shipbuilding industry in various regions. Finally, the absolute convergence model was used to examine the differences in the convergence of green TFP growth in the shipbuilding industry in various regions.

4.1 MEASUREMENT METHODOLOGY

Measuring green total factor productivity is the core link of this paper. Researchers start measuring from different perspectives. By combing the literature, they can be divided into parameter method and non-parameter measurement. The parameter method needs to set the production function in advance and assumes that the production process is constant in scale returns, mainly including the C-D function method, algebraic exponential method, transcendental logarithmic production function and stochastic frontier analysis method (SFA). The CD production function has been widely used since it was proposed, by assuming technical neutrality to study the relationship between factor input and production, but in actual economic production activities, the impact of factor input on output is not only related to the amount of factor input, but also related to Related to other elements. The algebraic index method uses all input element weighted indexes and output indexes, but the heterogeneity of input and output needs to be considered in the index selection, and the strong assumption that the marginal productivity is constant does not apply to actual research. Beyond the logarithmic production function method, the input elements become elastic and the square response surface has strong applicability and easy to estimate, but the measurement model is complex and rarely used. In recent years, the constant elastic substitution production function method (CES) has shown certain advantages in studying the impact of environmental regulation on the economy. In the past, it was rarely used because the function form is more complicated, but it is significantly better than the CD function in theory. There is a strong theoretical basis for analyzing the effect of environment on green total factor productivity. The stochastic frontier production function method considers the relative technical efficiency and avoids the interference of random disturbance terms, but the method still needs to assume the distribution form of the production function.

The mainstream of the non-parametric method is Data Envelopment Analysis (DEA), which constructs an effective production frontier through the decision-making unit in the sample and calculates the green total factor productivity. The DEA method is an evaluation method based on the concept of relative efficiency, using convex analysis and linear programming as tools, and uses mathematical programming to calculate and compare the relative efficiency between decision-making units. In the application, the decision-making unit is required to have the same performance target, and the decision-making unit is regarded as a "black box" so as not to assume the production function form. Compared with the parameterized method, the production function needs to be assumed. The DEA method builds the production frontier from the input and output of the decision unit, which effectively avoids the errors caused by strong assumptions such as model construction differences, random disturbances, and positive and negative distributions. It also allows multiple output.

In summary, the price of pollution emissions and energy input is difficult to define. Although the parameter method is favored in the analysis of general total factor productivity, it is not suitable for the study of green total factor productivity. This article uses DEA's ML index to measure the green total factor productivity of the shipbuilding industry. The environmental technical efficiency function in the model refers to the definition of Färe et al (Färe, Grosskopf, & Yaisawang, 1993).

4.1.1 DEA-SBM MODEL

Assessing relative efficiency based on angles and radials is a characteristic of classic DEA. Based on angles, it is required to set the input/output orientation before the measurement. Radial-based measurement cannot truly reflect the actual situation when there are non-zero relaxation variables in the decision unit. Therefore, the non-radial and non-angular SBM model can effectively overcome the above problems and is widely used by researchers. To facilitate subsequent modeling, p(x) is used to represent the output set, the input element vector is represented by X=$(x_{ij}) \in R^{+}_{n\times m}$, and the expected output vector is represented by$Y^g = (y^g_{ij}) \in R^{+}_{u\times m}$ indicates that the undesired output vector is represented by $Y^b = (y^b_{ij}) \in R^{+}_{v\times m}$. $(y, b) \in p(x)$, let 0 ≤ θ ≤ 1, if (θ y, θb) ∈ p (x) indicates that the desired output is free disposability. Assuming that the production set is a closed set and there are bounded solutions, the environmental technology function can be modeled as:

$$p(x) = \{(x, y^g, y^b) | x \geq X\lambda, y^g \leq Y^g\lambda, y^b = Y^b\lambda, \textstyle\sum_{i=1}^{m}\lambda = 1,\ \lambda \geq 0. \quad (1)$$

λ in equation (1) represents the weight of the cross-section input-output data, and the weight variable is non-negative and $\sum_{i=1}^{m}\lambda = 1$ constraints represent variable returns to scale (VRS).

The SBM efficiency measurement model considering undesired output comprehensively analyzes the relationship between input, output and pollution, and the slack problem in efficiency evaluation is also well solved(Kaoru & M). The non-angular and non-radial data envelope analysis method based on slack variables was first proposed by Tone (Tone, 2001), and Fukuyama et al. (Fukuyama & Weber, 2001) generalized the directional distance function on the basis of it to develop non-radial and non-angular DDF and improve the accuracy of efficiency measurement. Combined with the addition of environmental variables in the study, the DDF and the SBM model with increased undesired output are proposed, which is the linear programming model of this study (Serrano, Guerrero, Gang, Zervopoulos, & Moreno, 2014).

$$\min \rho^* = \frac{1-\frac{1}{n}\sum_{i=1}^{n} s_i^- / x_{io}}{1+\frac{1}{u+v}\left(\sum_{j=1}^{u}\frac{s_j^g}{y_{j0}^g}+\sum_{j=1}^{v}\frac{s_j^b}{y_{j0}^b}\right)} \tag{2}$$

$$\text{s.t. } x_0 = X\lambda + s^-,\ y_0^g = Y^g\lambda - s^g, y_0^b = Y^b\lambda + s^b,\ \ \lambda, s^g, s^b, s^- \geq 0$$

In model (2), when $s^- \in R^n$and $s^b \in R^v$ are greater than zero, it means that there are too many inputs and undesired outputs, respectively, and $s^g \in R^v$ is greater than zero, which means that the expected output insufficient. The numerator represents the average scalable ratio of the actual input of the decision unit relative to the technological frontier, and the denominator represents the average scalable ratio of the actual output relative to the production technological frontier.

4.1.2 MALMQUIST LUENBERGER INDEX

Shepard's output distance function is widely used in early production efficiency calculations. It assumes that output is weakly disposable, that is, if a given output set is feasible, then there must be an input set to reach the output Any reduction of the output aggregate is also feasible. Färe et al. proposed the Manquist Productivity Index, which was based on the M index and considered the unexpected output expansion to obtain the ML index. In addition, when choosing the ML index measurement, you need to choose the cost minimization goal or the profit maximization goal, that is, whether to use the input method or the output method. Chamber and others improved the Luenberger productivity index, and generalized the Luenberger productivity index by integrating multiple objectives such as minimizing costs and maximizing returns (Chambers R G, Färe R, & Grosskopf, 1996). Considering the field of the shipbuilding industry, decision makers are more concerned with output. In this paper, the output method is used to construct the objective function. In addition, the calculation basis of green total factor productivity is the possible output set after integrating undesired indicators, set as g=(g_y,-g_b) as the direction vector, representing the direction vector of the increase and decrease of good output and bad output , Means maximizing the total output of the shipbuilding industry and minimizing pollution emissions (Chambers & Fare, 1996; Y. Chung & Färe, 1995). Introducing the directional distance function to calculate the efficiency of the decision unit:

$$max\beta = \vec{D}_0^t(x^t, y^t; g_y, -g_b)$$

$$s.t.\ \sum_{k=1}^{K} z_k^t y_{kj}^t \geq y_{k'j}^t + \beta g_{yj}^t, j = 1,2,\dots,u$$

$$\sum_{k=1}^{K} z_k^t b_{ks}^t \geq b_{k's}^t - \beta g_{bs}^t, \qquad s = 1,2,\dots,v$$

$$\sum_{k=1}^{K} z_k^t x_{ki}^t \leq x_{k'i}^t,\ \ i = 1,2,\dots,n \tag{3}$$

Considering the undesirable production model (3), z_k^t represents the weight of the cross-sectional observation value, k=1,2,...,K decision units. After solving the linear programming to obtain the directional distance function, the green total factor productivity index ML at period t+1 is:

$$ML_t^{t+1} = \{\frac{1+\vec{D}_0^t(x^t,y^t,b^t;g^t)}{1+\vec{D}_0^t(x^{t+1},y^{t+1},b^{t+1};g^{t+1})} \times \frac{1+\vec{D}_0^{t+1}(x^t,y^t,b^t;g^t)}{1+\vec{D}_0^{t+1}(x^{t+1},y^{t+1},b^{t+1};g^{t+1})}\}^{1/2} \quad (4)$$

ML index measurement needs to be decomposed into technical efficiency changes (TEC) and technological progress changes (TC) by means of linear programming. TEC is derived from pure technical efficiency changes and production scale efficiency changes, and TC represents the increase in output from technological improvement.

$$TEC = \frac{1+\vec{D}_0^{t+1}(x^t,y^t,b^t;g^t)}{1+\vec{D}_0^{t+1}(x^{t+1},y^{t+1},b^{t+1};g^{t+1})} \quad (5)$$

$$TC = \{\frac{1+\vec{D}_0^{t+1}(x^{t+1},y^{t+1},b^{t+1};g^{t+1})}{1+\vec{D}_0^t(x^{t+1},y^{t+1},b^{t+1};g^{t+1})} \times \frac{1+\vec{D}_0^{t+1}(x^t,y^t,b^t;g^t)}{1+\vec{D}_0^t(x^t,y^t,b^t;g^t)}\}^{1/2} \quad (6)$$

The above indicators ML, TEC, and TC are positive and negative, respectively, indicating that productivity is increased or decreased, efficiency is increased or decreased, and technology is increased or decreased. Under the assumption of variable returns to scale, four directional distance functions are solved, and two linear programs solve the current directional distance function. The corresponding data sets are t and t+1. The other two directional distance functions, namely the input and output values based on periods t+1 and t, need to be solved with reference to the techniques of periods t and t+1, respectively.

4.2 DATA RESOURCE AND VARIABLE SELECTION

As a national key development industry, the shipbuilding industry is also a strategic export industry. Following the rise of the Korean shipbuilding industry, the Chinese government began to attach importance to the development of the shipbuilding industry. In 2003, the Outline of the National Marine Economic Development Plan clearly stated the strategic goal of "gradually building a maritime power" and made the shipbuilding industry a strategic industry. Domestic and foreign organizations have a large amount of statistical data on their relevant information and the statistical caliber is relatively uniform. Shipbuilding companies have a lot of infrastructure for lifting, transportation and welding operations, and the production environment is complex. A large amount of data needs to be collected in the safety production management process. With the development of scientific and technological information technology and the improvement of precision monitoring and measurement equipment, the information collected by the shipbuilding industry is becoming more and more comprehensive. However, the main public statistics still come from the macro level, and the data at the micro level for regions and individual companies is relatively lacking. Therefore, the research data of this article mainly comes from the public statistical yearbook.

4.2.1 DATA RESOURCE

Based on the panel data of China's shipbuilding industry by region, measure the green total factor productivity and evaluate the impact of environmental regulations on economic efficiency. Considering the availability of data, it is difficult to find complete ship industry environmental data in the China Environmental Statistics Yearbook. For pollution emission data, the regional data is mainly used to estimate the ship industry emission data. In addition, considering the changes in the statistical standards of pollution emissions in 2016, the time span of this study was set to 2004-2015. Due to the lack of statistical data for some regions in the China Shipbuilding Industry Yearbook, considering the continuity of the data and the contribution of shipbuilding output, the eastern regions of Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Tianjin, Hebei, Liaoning, Shandong and central regions were selected. The shipbuilding industry in 15 provinces and municipalities including Jiangxi, Anhui, Hubei, Hunan, and Guangxi and Chongqing in the western region is the research object. Taking account the institutional differences, Hong Kong and Macau are not included in the special administrative regions, and there is no data for Taiwan. To use the DEA method, you need to select input and output variables, and consider capital, labor, and energy as input variables. In the output variables, pollution emissions are included to form expected output and undesired output. The specific measurement indicators and data processing are described as follows:

4.2.2 INPUT FACTOR

Labor input and capital input are essential factor inputs in the production process. As a labor-intensive and capital-intensive industry, labor and capital input are very critical. In addition, in order to achieve the national energy saving and emission reduction goals, the energy consumption of the shipbuilding industry has become the focus of this study. The connotations and measurement indicators of the three main input elements are as follows:

Labor input. Scholars at home and abroad generally believe that labor time is a better measure of indicators, but the statistics on the time investment of workers in the shipbuilding industry are more complicated, and there is a lack of public statistical data on this in China. Therefore, the average annual number of employees in the shipbuilding industry by region is selected. This indicator can effectively reflect the labor input of the shipbuilding industry. The data comes from the China Shipbuilding Industry Statistical Yearbook.

Capital investment. Fixed assets and capital stock are generally considered to be the most reliable estimates, but considering that some existing relevant statistics do not have the variable index of fixed assets in the shipbuilding industry, and the investment in shipbuilding and repair facilities accounts for the largest proportion of shipyard fixed investment assets It is reasonable to select the sum of shipbuilding berths and docks for repairing and building ships of over 10,000 tons to measure the capital investment. The data comes from the China Shipbuilding Industry Yearbook.

Energy consumption. There is no detailed statistical data on the energy consumption of the shipbuilding industry. It is estimated by multiplying the ratio of the operating income of the shipping industry enterprises to the total industrial operating income, and multiplying the total energy consumption of the industrial enterprises in various regions. The price is reduced to eliminate the impact of prices. The data comes from "China Industrial Economic Database" and "China Energy Statistical Yearbook".

4.2.3 OUTPUT FACTOR

In the evaluation of the green total factor productivity of the shipbuilding industry, there are two main output variables involved. One is the expected output variable for the purpose of production and operation, which is the main concern of production decision makers. The main indicators representing expected output variables include main business income, profit, and total output. The second is that under environmental regulations, companies are faced with the pollution control costs faced by government regulation. The production goal of corporate decision makers is to maximize expected output while reducing pollution emissions as much as possible. Pollution emissions as undesirable output has become a concern for corporate decision makers. The choice of indicators representing undesirable output varies greatly depending on the research subject.

Expected output. The main output of the shipbuilding industry is the amount of shipbuilding, and it is also the main goal of the competition among shipbuilding companies. The measurement of the output of the shipbuilding industry in the world mainly selects the corrected tonnage of ships completed, which effectively overcomes the differences in ship types and the complexity of ship construction.

Unexpected output. There is no fixed standard for the selection of this indicator, and it is relatively open. Watanabe (Watanabe & Tanaka, 2007) and others chose sulfur dioxide as an undesirable output. In view of the large amount of solid waste pollution in the production of the shipbuilding industry, we selected three indicators such as industrial sulfur dioxide emissions, industrial chemical oxygen demand emissions and industrial solid wastes, combined with the ratio of the shipbuilding main business revenue to the regional industrial main business revenue. Pollution emissions from the shipbuilding industry. Unlike most studies that use one or several environmental pollution indicators, this research used the entropy method to comprehensively estimate the environmental pollution emission index. Drawing on this idea, this paper uses the TOPSIS evaluation method that approximates the ideal solution to estimate the total pollution emission index of each region. The TOPSIS method is based on the Euclidean distance function. By defining the positive ideal solution and the negative ideal solution of the decision variable, and then finding a solution in the feasible solution, the distance from the positive ideal solution is the closest and the distance from the negative ideal solution is the farthest. This method normalizes the original data to eliminate the index dimension, which can not only make full use of the original data but also eliminate different index quantities, and has the advantages of real, intuitive and reliable. The specific evaluation steps are as follows:

①. Normalize the original data according to $y_{ij} = X'_{ij} / \sqrt{\sum_{i=1}^{n} X'^2_{ij}}$. The normalization processing here includes co-homogenization and normalization. The chemical treatment can transform the low-excellent index into the high-excellent index, where y_{ij} is the standard value of the ith region in the jth emission index.

②. Calculate the weight of the emission index j of area i to the total emissions, the calculation formula is: $p_{ij} = y_{ij} / \sum_{i=1}^{n} y_{ij}$, And calculate the entropy $e_j = -\left(\frac{1}{\ln n}\right) \sum_{i=1}^{n} \left(p_{ij} \ln p_{ij}\right)$ and coefficient of difference $g_j = 1 - e_j$。

③. Further calculate the weight of j emission indicators, the weight is expressed as $w_j = \frac{g_j}{\sum_{i=1}^{n} g}$, process a weighted norm matrix $r_{ij} = w_j \times y_{ij}$。

④. Using r_{ij} to calculate the distance from each value to the maximum and minimum values as D^+ D^-, which respectively represent the distance of the ideal solution and the distance of the negative ideal solution. Use two distance values to calculate the comprehensive evaluation value, $C_i = D^- / (D^- + D^+)$ represents relative proximity, the larger the C value, the greater the pollution emissions from the shipbuilding industry in the assessed area。

The indexes such as sulfur dioxide emissions, chemical oxygen demand emissions, and solid waste emissions, which represent environmental pollution indicators, were substituted into the TOPSIS model to estimate the comprehensive indicators of undesired output in 15 shipping industry areas, and the undesired output obtained The statistical description of the evaluation results is shown in Table 4-1:

Table 4-1 Statistical Description of Unexpected Production Indicator

	Obs	Mean	Var	Max	Min
Unexpected Output	180	1.221	0.467	0.4	3.08

Observation statistics description results show that the total observation value is 180, the minimum value of the unintended output comprehensive index is 0.4, and the maximum value is 3.08. Each shipbuilding industry has differences in the pollution situation in different years of each region. As a result, all variables for estimating the green total factor productivity of China's shipbuilding industry are obtained.

4.3 EVALUATION RESULTS

After determining the input indicators, expected output indicators and undesired output indicators, the data can be sorted and substituted into the data envelopment analysis (DEA) model to evaluate the green total factor productivity of the shipbuilding industry. It is worth noting that the basic assumption of using the DEA model is "isotropic". The connotation of this assumption is that the output cannot be reduced when the input is increased. If the input increases and the output decreases, the same direction is not satisfied. Assumptions, and cannot be measured using the DEA model. Therefore, first of all, the Pearson correlation test is performed on the indicators of labor, capital, energy, expected output and undesired output. The Pearson correlation coefficient is an improvement of the cosine similarity in the absence of dimension values. A common method for measuring similarity is that the output value is between -1 and 1. A positive value indicates a positive correlation between the two, a negative value indicates a negative correlation between the two, and zero indicates no correlation. The test results show that the input and output index test results are statistically significant and the correlation coefficient is positive at a 1% significance level.

The test data in Table 4-2 shows that, except for capital and undesired output, the correlation between capital and energy is relatively low, at 0.19 and 0.295, respectively. The correlation between capital and labor is also relatively low, and the other indicators are related to each other. The sex coefficients are all high and all are highly statistically significant.

Table 4- 2 Pearson Test

	Labor	Capital	Energy	Expected Output	Unexpected Output
Labor	1	0.363***	0.883***	0.893***	0.595***
Capital		1	0.295***	0.604***	0.190**
Energy			1	0.802***	0.785***
Expected Output				1	0.476***
Unexpected Output					1

Note: **, *** represent significant at 5%, 1% level respectively

4.3.1 GTFP AND DECOMPOSITIONS IN CHINESE SHIPBUILDING INDUSTRY

Using the above method and the collected sample data, based on the output-oriented non-radial and non-angle SBM method that also considers the undesired output, the green total factor productivity of the shipbuilding industry in various regions is measured. In theory, some scholars believe that undesirable output is weakly disposable, that is, reducing bad output will also reduce good output. However, some scholars believe that undesirable output has strong disposability, that is, reducing bad output does not affect the output of good output. However, considering the weak disposition of undesired output, the practical solution will be reduced in practical solutions. Therefore, this article adopts the approach of most scholars and does not add weak disposability to undesired output. Calculate the ML index of China's shipbuilding industry as a whole and the ML index of the shipbuilding industry of various regions, and dynamically analyze the development and changes of China's shipbuilding industry as a whole and the development differences between regions from a time series perspective. But the index does not reflect the green total factor productivity itself, in fact it represents the growth rate of green total factor productivity. Therefore, this article refers to Qiu Bin's processing method and selects 2004 as the base year to calculate the green total factor productivity of each region in the remaining years.

Using MAXDEA for implementation, first of all, the overall data of the national shipbuilding industry is substituted into the model to calculate the change trend of green total factor productivity with time, and the change trend of two decomposition indicators of green technology efficiency and green technology progress with time is observed (see Table 4- 3).

Different from the existing research that draws the conclusion that traditional total factor productivity continues to increase, from the perspective of time series, the changes in green total factor productivity of China's shipbuilding industry show a cyclical change that rises first and then decreases. The growth of green total factor productivity reached a peak in 2007-2008, and then showed a downward trend. The main explanation is that the prosperity of the marine market during this period led to the development of the shipbuilding industry, and a large number of import and export trades promoted shipowners' demand for ships. At the same time, China has further liberalized its ship export policy and scrambled for orders in the international market. The industry chain reaction has brought about the development of the shipbuilding industry. Except for the negative growth in 2004-2005 and 2012-2013, there have been considerable growth in other years. There are two main explanations for this. On the one hand, from 2004 to 2005, the Chinese shipbuilding industry responded to national policies to develop the shipbuilding industry, investing a large amount of labor capital and energy and other factors, which also expanded the pollution emissions of the shipbuilding industry to a corresponding extent, thereby reducing green total factor productivity. On the other hand, observing the development cycle of China's shipbuilding industry, it is not difficult to find that 2012-2013 was a trough period in the shipbuilding market, and the reduction in shipbuilding output led to a drop in productivity. Observe the two decomposition indicators of green technology progress and green technology efficiency in these two periods. In the first year, the technical efficiency index is negative growth, and in the second year, the technical progress index is negative growth. It can be considered that technical efficiency and technological progress have jointly promoted the green total factor productivity of the shipbuilding industry, and the effect of green technical efficiency is relatively stable, and has always shown a positive driving effect. In comparison, the effect of green technological progress fluctuates greatly, and some years have a negative effect.

Table 4-3 Changes of GTFP and decomposition indices in shipbuilding industry from 2004 to 2015

Year	TEC	TC	GTFP
2004-2005	0.987	1.353	0.987
2005-2006	1.164	1.561	1.042
2006-2007	1.1	1.197	1.151
2007-2008	1.646	0.928	1.439
2008-2009	1.338	1.473	1.025
2009-2010	2.287	0.955	1.643
2010-2011	2.174	1.082	1.209
2011-2012	1.723	1.034	1.179
2012-2013	1.676	0.984	0.956
2013-2014	1.784	1.038	1.033
2014-2015	1.989	0.970	1.145
Avg	1.624	1.143	1.138

Note: Each index minus 1 is its growth rate.

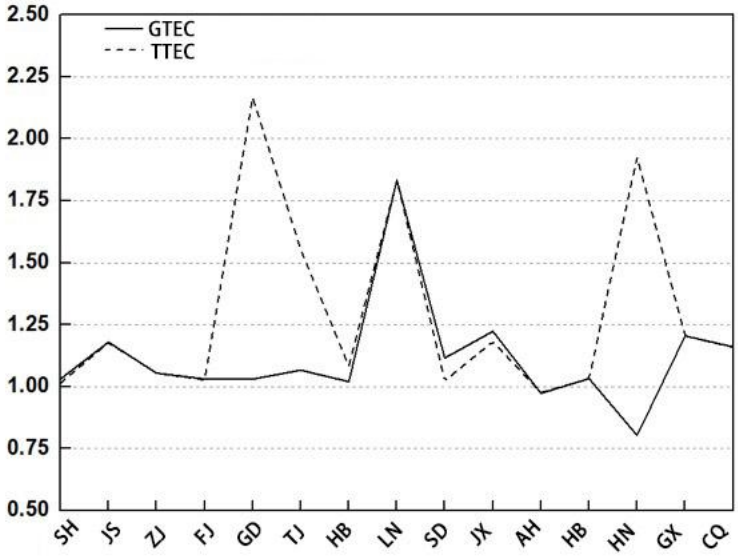
4.3.2 GTFP AND DECOMPOSITIONS AT DEFFIRENT REGIONS

While the development of China's shipbuilding industry is affected by the central government's policy, it is also affected by regional development. With the implementation of the reform and opening-up policy, China has given priority to the development of coastal cities such as Shenzhen and Zhuhai, and implemented a development strategy of reforming and opening up to get rich first and driving wealth later. The region where each shipbuilding industry is located is affected by the time of regional development. The economic development level of the east and west regions is uneven. The development of coastal cities in the east is relatively fast while the level of development in the west is relatively backward. The degree of industrialization is different. There is also a clear difference in factor productivity levels. Therefore, the calculation of green total factor productivity based on the shipbuilding industry data of various regions is of guiding significance in the development of industrial regions. Panel data of 15 provinces and municipalities including Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Tianjin, Hebei, Liaoning, Shandong, and Jiangxi, Anhui, Hubei, Hunan, and Guangxi and Chongqing in the central region of the eastern region were selected for analysis The green total factor productivity of China's shipbuilding industry is compared with the results of traditional total factor productivity measured by considering only general capital labor input and expected output. In addition, the ML index is decomposed by linear programming to obtain two decomposition indexes of technical efficiency and technological progress. The comparative analysis of the green technical efficiency and traditional technical efficiency of the Chinese shipbuilding industry, the two sets of decomposition indexes of green technical progress and traditional technical progress, the results See Table 4-4:

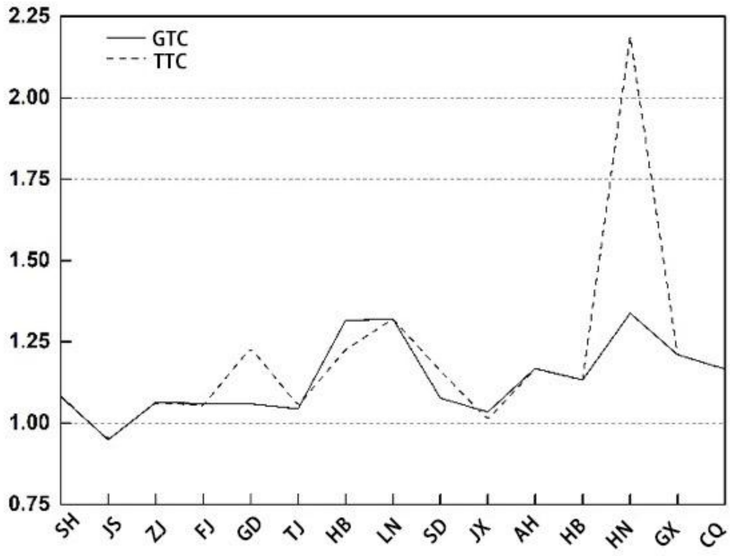
Table 4-4 GTFP and its decomposition index of shipbuilding industry in different regions

Area	GTEC	GTC	GTFP	TTEC	TTC	TTFP
Shanghai	1.030	1.081	1.082	1.014	1.084	1.699
Jiangsu	1.179	0.949	1.089	1.178	0.949	1.952
Zhejiang	1.054	1.064	1.073	1.054	1.063	1.906
Fujian	1.031	1.060	1.078	1.027	1.054	1.554
Guangdong	1.030	1.059	1.429	2.166	1.231	1.697
Tianjing	1.066	1.044	1.630	1.553	1.054	2.118
Hebei	1.020	1.316	1.116	1.083	1.226	1.966
Liaoning	1.833	1.320	1.211	1.833	1.320	2.363
Shandong	1.115	1.077	1.016	1.023	1.161	0.549
Jiangxi	1.223	1.034	1.089	1.182	1.011	1.321
Anhui	0.973	1.168	1.037	0.975	1.167	0.262
Hubei	1.032	1.133	1.138	1.032	1.132	2.234
Hunan	0.803	1.338	3.330	1.924	2.188	1.139
Guangxi	1.204	1.210	1.142	1.204	1.210	1.101
Chongqing	1.160	1.166	1.118	1.159	1.165	1.902
Avg	1.117	1.135	1.305	1.294	1.201	1.584

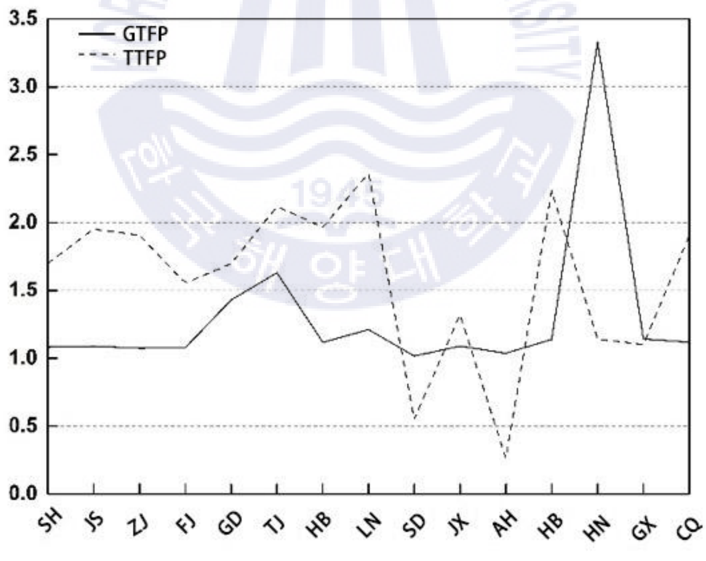
Note: Each index minus 1 is its growth rate.



(a)



(b)



(c)
Figure 4-1 Compared analysis of GTFP and decomposition indexes

The chart analysis shows that after the increase of environmental constraints, the overall average productivity of the shipbuilding industry is lower than the traditional total factor productivity. The traditional total factor productivity and the green total factor productivity of the shipbuilding industry are 1.584 and 1.305, respectively. And without considering environmental regulations, the technical efficiency of the shipbuilding industry in Guangdong, Liaoning and Hunan has been significantly overestimated. It can be seen that the efficiency evaluation of traditional measurement methods only considering the expected output tends to overestimate the total factor productivity of the shipbuilding industry. The development of the shipbuilding industry has the phenomenon of externalizing environmental pollution to achieve growth. During the study period, the average value of green total factor productivity of the shipbuilding industry was all greater than 1, and the phenomenon of green technological progress was obvious, which benefited from the implementation of my country's escalating shipbuilding environmental protection policy. In response to the International Maritime Organization (IMO)'s proposal that ships will not be vulcanized in 2020, improving the environmental protection requirements of the ship from design to construction and operation, China has put forward standards higher than international organizations in the construction and operation of ships to promote Chinese ships The industry has achieved a green transformation, such as restricting the use of low sulfur oil in the Yangtze River Delta region. During the period from 2004 to 2008 and since 2011, the green total factor productivity of the shipbuilding industry has increased to a certain extent. The former benefited from the country's "Eleventh Five-Year Plan" clearly defined the green sustainable development strategy. The market is lower, the number of orders received by ships is reduced, and the undesired output is also reduced when the expected output is reduced, which promotes the increase of the green total factor productivity of the shipbuilding industry; The "Interim Provisions on the Management Regulations of the Shanghai Maritime Safety Administration on the Prevention and Control of Marine Environment Pollution by Ships for Oil Supply and Pollution Operations" issued in 2016 promotes the strengthening of environmental protection measures by shipyards in the Yangtze River Delta region, and the concept of environmental protection in the shipbuilding industry requires that pollution prevention facilities must be designed at the same time as the main project. Simultaneously construct and put into production at the same time. Observing the magnitude of change, the average growth rate of traditional total factor productivity from 2004 to 2015 was 58.4%, of which technological efficiency increased by 29.4% and technological progress increased by 20.1%. After considering the undesired output, the total factor productivity of the shipbuilding industry increased by an average of 30.5%, of which technological efficiency and technological progress increased by 11.7% and 13.5%, respectively. It can be seen that technological progress is the main source of growth in total factor productivity of my country's shipbuilding industry, and technical efficiency plays a role in promoting it to a certain extent. It is enough to show that under the rigid constraints of continuously strengthening environmental regulations, the development of the shipbuilding industry mainly depends on technological innovation and progress. In practice, the Ministry of Transport of the People's Republic of China implemented the "Regulations on the Prevention and Control of Marine Environment Pollution by Ships and Related Operations" on May 23, 2017, and proposed to strengthen ship pollution control. The investment in environmental protection technology and facilities is the key.

4.4 CONVERGENCE OF GREEN TOTAL FACTOR PRODUCTIVITY GROWTH

The above comparative analysis found that the green total factor productivity, green technical efficiency and green technological progress of China's shipbuilding industry are somewhat different among shipbuilding centers, and the green total factor productivity shows periodicity in time series. Next, the absolute β convergence test is used to analyze the regional differences in the growth rate of green total factor productivity in the shipbuilding industry.

The absolute β convergence test is adopted for the provinces and cities where the shipbuilding industry is divided into the eastern, central and western regions. Based on the absolute β convergence test model, that is to say, the "catch-up effect" makes the green total factor productivity of the shipbuilding industries in each region ultimately at the same steady state Growth level, TFP growth rate is negatively correlated with the initial level. The panel model is:

$$\ln(y_{it}) - \ln(y_{i,t-1}) = \alpha_{it} + \beta ln(y_{i,t-1}) + u_{it} \quad (7)$$

Table 4-5 Absolute Beta Convergence Test

	China	East Area	Mid Area	Western Area
β	-0.636**	-0.765**	-0.566**	-0.429*
T statistic	-9.02	-8.08	-4.10	-2.67

Note: ***, ** indicate significant at 1% and 5% respectively.

Through model testing, with all regions as a whole, β is significantly negative, the shipbuilding industry as a whole has an absolute convergence trend, and the growth gap in green productivity between regions has gradually narrowed. In terms of dividing the eastern, central and western regions, there is also a clear convergence trend in the major regions. In other words, with the passage of time, the differences in the growth of the shipbuilding industry in various regions have gradually narrowed and tend to be balanced, which is also certain To a certain extent, the effectiveness of the continuous merger and expansion of Chinese shipbuilding industry enterprises has been verified.

CHAPTER 5: DETERMINANTS OF GREEN TOTAL FACTOR PRODUCTIVITY OF CHINESE SHIPBUILDING INDUSTRY

Through the above analysis, we can see that the traditional total factor productivity evaluation that does not consider environmental regulations and pollution emissions overestimates the productivity of China's shipbuilding industry and compares it with green total factor productivity. It is found that Guangdong, Liaoning and Hunan and other regions The difference is obvious. However, the convergence test results show that the green total factor productivity of the shipbuilding industry in various regions shows a convergence trend. The evaluation of the green total factor productivity of the shipbuilding industry gives an intuitive development status, however, the internal factors that affect the green total factor productivity are unknown, so this chapter will focus on exploring the green total factor of the Chinese shipbuilding industry through econometric methods Factors affecting productivity.

5.1 VARIABLE SELECTION

The development status of China's shipbuilding industry's green total factor productivity and the differences among regions have been evaluated by internal factors such as input and output. However, the development of the shipbuilding industry is still affected by many factors. Starting from the research purpose of this article, with the intensity of environmental regulation as the main explanatory variable, it focuses on exploring its role in China's shipbuilding industry. In addition, factors such as macro-environmental factors, the level of scientific and technological progress, and export policies are considered as control variables. In practice, many factors affect the green total factor productivity of the shipbuilding industry, combined with the availability of data and the operability of empirical analysis. The above analyzes the changes in the green total factor productivity of the shipbuilding industry from internal influencing factors. In this chapter, the indicator is used as the explanatory variable, and the annual growth rate of the regional GDP, technical level, export dependence and environmental regulations are selected to analyze the greenness of the shipbuilding industry. Factors affecting total factor productivity.

5.2 VARIABLE DESCRIPTION

（1） Annual GDP growth rate

The annual economic growth rate measures the changes in the economy between two years and is a basic indicator that reflects whether the economy is dynamic. The shipbuilding industry is a capital-intensive heavy industry enterprise, and the construction of shipbuilding equipment and production lines requires a large amount of capital investment. While the Chinese shipbuilding industry benefits from central government policies, it also depends on the support of local financial policies. In addition, the Chinese shipbuilding industry aims at the international market and focuses on ship exports, which makes a great contribution to the GDP of the region where it is located, and also highly relies on the economic development of the region. The more active the shipbuilding industry center, the higher the total shipbuilding volume, such as Shanghai, Zhejiang and other regions.

（2）Techinque level

The development of China's shipbuilding industry has changed from labor-intensive to capital- and technology-intensive industries, and current environmental protection regulations are continuously strengthened to further promote technological progress and innovation. Prevention of marine pollution is imperative. As 2020 IMO will continue to introduce relevant policies, the application of ballast water treatment schemes, exhaust gas desulfurization schemes, and the use of low-sulfur oil will continue to be the focus of the international community. With the strengthening of environmental protection regulations in the manufacturing industry in China, some shipping companies face a large amount of pollution control costs due to pollutants such as waste water, waste gas and waste discharged every year. Replacing old production equipment, replacing unclean energy and investing in environmentally friendly materials all require technical support. In addition, the international ship market is changing rapidly. In the face of rising international crude oil demand, shipowners are demanding larger capacity cruise ships. On the contrary, there is still a problem of excess capacity in the bulk carrier market. Large-scale oil tankers and container ships are most closely related to technological R&D and technical level. In addition to relying on central government equipment for technology investment in the shipbuilding industry in various regions, more local government policy support and technological advancement in the region. The level of technology is also reflected in the supply of high-tech laborers. The main reasons for the “difficulty in using work” and “expensive use of work” currently faced by the shipbuilding industry are also due to the lack of talent. In short, the internal expenditures of research and experimental development funds in various regions include both capital equipment investment and R&D personnel salaries, which are ideal for measuring technological progress.

（3）Dependency on foreign exports

The ship market is a highly internationalized market. In 2018, China’s completed export ships accounted for 91% of shipbuilding completions, and its dependence on the international market will also affect the green transformation of the shipbuilding industry. Since the reform and opening up, China has adopted an export-oriented development strategy, by underestimating the RMB exchange rate, and adopting export incentives and other policy measures to reduce the production cost of the shipbuilding industry, so that more domestic resources flow to the external sector. Developed shipbuilding countries purchase advanced technology. Affected by policy orientation, China's shipbuilding industry's dependence on foreign exports is relatively high, but it gradually decreases as domestic technology improves and domestic market demand increases. To explore the impact of the degree of dependence on external exports on the green total factor productivity of the shipbuilding industry, this paper uses the proportion of the annual export completion of ships in each province to account for the degree of dependence on external exports.

（4）Environmental regulation

There are controversial views on the impact of environmental regulation on industrial productivity, and there are large differences in the measurement methods of environmental regulation. The specific environmental regulation programs have their own characteristics. The two key issues involved in the measurement of the intensity of environmental regulation are multidimensionality and comparability. Multidimensionality is reflected in the diverse environmental regulation measures faced by different regions, industries, and enterprises. At the same time, the pollution emissions of enterprises in the production process are also different. the same. Comparability is an important premise for evaluating environmental regulation through empirical data, and is a relative concept. At present, the methods for measuring the intensity of environmental regulation mainly include measurement methods based on pollution control inputs, measurement methods based on pollution emissions, and measurement methods based on comprehensive evaluation. Considering that the clean environment has the characteristics of externalities and public products, it cannot be deployed by invisible hands in the market. The investment in pollution control mainly depends on the macroscopic deployment of hands that are visible to the government. The government's investment in pollution control includes environmental and natural resource protection budget expenditures and the government's efforts in monitoring and punishing enforcement. The measurement based on pollution emissions objectively reflects the performance of environmental regulation, but due to regional policy differences, it often lacks comparability. The method based on comprehensive evaluation is mainly applicable between countries and regions, and the key point is the determination of indicators and weights. "China Environmental Yearbook" provides detailed regional and industry pollution control investment, so domestic scholars widely use the measurement method based on pollution control input, this paper uses the proportion of environmental pollution control investment in each province and city as a measure of the intensity of environmental regulation Ideal.

5.3 REGRESSION ANALYSIS

Construct the panel model according to the selected variables:

$$\ln GTFP_{it} = \alpha_0 + \alpha_1 lnRGDP_{it} + \alpha_2 lnRD_{it} + \alpha_3 lnEX_{it} + \alpha_4 lnER_{it} + \varepsilon_{it} \quad (8)$$

Here， $RGDP_{it}$、 RD_{it}、 EX_{it}、 ER_{it} respectively represent the annual growth rate of GDP, technical level, dependence on foreign exports and the intensity of environmental regulation in year t of region i， ε_{it} is Random interference. See Table 5-1 for the statistical description results of all regression variables.

Table 5-1 Descriptive statistics of regression dataset

Variable	Obs	Mean	Std	Min	Max
lnGTFP	178	0.033	0.617	-4.834	3.296
lnRGDP	180	-1.998	0.579	-6.514	-0.956
lnRD	180	14.54	1.080	11.684	16.707
lnEX	170	-0.735	0.892	-4.041	1.777
inER	180	0.130	0.378	-0.916	1.125

Before performing regression analysis, it is necessary to determine the heteroscedasticity problem that cannot be captured in the model. Based on the model, the Hausman test is used to decompose the residual items to determine whether the model uses a random utility model or a fixed utility model. For the research in this paper, the assumption corresponding to the fixed effect is that the production scale of each shipping company is different, but it is measurable. Because, after controlling most variables, the difference between shipyards is only the difference in base. The random effect assumes that after controlling most variables, the production base of each shipyard is still the same, but some shipyards are more unstable than others. The test result rejects the assumption that the interference term is not related to the explanatory variable, so the solid effect model (see Table 5-2) is applied. By ignoring some uncontrollable unstable factors in the model, the estimation caused by the assumption that the shipyard size has always been avoided is avoided. Biased. In addition, the fixed-effect model has obvious advantages of convenient estimation, while the random-effect model is more troublesome. Most of the time when using the random effect model is only a feasible generalized least squares estimate (FGLS), the model only approximates the effective generalized least squares estimate (GLS) when the covariance matrix gradually converges.

Table 5-2 Hausman Test

	fe	re	Difference	S.E
lnRGDP	0.086	0.064	0.021	0.05
lnRD	0.143	0.051	0.092	0.073
lnEX	-0.199	0.074	-0.125	0.062
lnER	0.308	0.157	0.151	0.122
chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)=7.80				
Prob>chi2 = 0.0991				

5.3.1 STATIONARY TEST

After determining whether the original time series data contains fixed effects or random effects, it is necessary to determine the invariance of the statistical properties of the series with respect to time translation and the stationarity of the data to avoid the existence of pseudo regression. That is, the ADF test is performed on the variables such as TFP, RGDP, RD, EX, and ER. The test is to check whether the characteristic equation of the difference equation of the sequence is less than 1, that is, whether it is within the unit circle. The results of the stability test on the residual decomposition of panel data are shown in Table 5-3:

Table 5- 3 Stationarity Test Results

Variable	t-value	Critical value			
		1% sig	5% sig	10% sig	
lnGTFP	-3.781	-2.10	-1.92	-1.83	Stable***
lnRGDP	-4.071	-2.10	-2.00	-1.96	Stable***
lnRD	-1.788	-3.83	-3.03	-2.66	Stable***
lnEX	-7.09	-3.86	-3.04	-2.66	Stable***
lnER	-1.88	-3.83	-3.03	-2.66	Stable***

Note: At 1% significance level, it is steadily indicated by ***, at 5% significance level, it is indicated by **, and at 10% significance level, it is indicated by *.

5.3.2 RESULTS EXPLANATION

After the above stationarity test, Stata software was used to perform OLS regression analysis on the factors affecting the green total factor productivity of the shipbuilding industry from 2005 to 2015. The results are shown in Table 5-4. Considering that the traditional static panel model has endogenous problems, the green total factor productivity of a certain area is often affected by the previous period, and after the pollution control infrastructure is built at one time, it will continue to be used for subsequent environmental protection work. In order to eliminate the error of the test results, this paper takes the first-order lag of green total factor productivity as an instrumental variable and constructs a dynamic panel model 1 for analysis. At the same time, consider that the R&D investment has a time lag. The current R&D investment often contributes to future productivity growth. Similarly, the first-order lag item of the R&D investment index is introduced into the model to build a dynamic model 2.

Table 5- 4 Variables Regression Results

	Fix Effect	Dynamic modle1	Dynamic modle1 2
$lnGTFP_{i,\ t-1}$	/	-0.2418***	-0.2383***
	/	(-2.97)	(-2.93)
$lnRGDP_{it}$	0.0856	0.127	0.1343
	(0.83)	(1.15)	(1.17)
$lnRD_{it}$	0.1425	0.1997*	/
	(1.55)	(1.88)	/
$lnRD_{i,\ t-1}$	/	/	0.183*
	/	/	(1.79)
$lnEX_{it}$	-0.1904**	-0.1965**	-0.1972**
	(-2.29)	(-2.15)	(-2.14)
$lnER_{it}$	0.3081*	0.3696*	0.3733**
	(1.71)	(1.97)	(1.99)
C	-3.5406*	-2.8241*	-2.5316*
	(-1.62)	(-1.91)	(-1.83)
R-squared	0.126	0.192	0.177

Note: ***, **, and * indicate that the results are significant at statistical levels of 1%, 5%, and 10%, respectively

In the empirical analysis, the logarithm of the original data is taken to maintain the stability of the data, and the regression analysis is supported by Stata software. On the whole, although the R^2 value is not large, the coefficients of the main explanatory variables of the dynamic panel model are mostly significant. The coefficients of GDP growth rate, technological progress, and environmental regulation are positive, and the coefficient of export dependence is negative. In addition to the GDP growth rate, All passed the test at the significance level of 1%, 5% and 10%. The macroeconomic environment, R&D investment in science and technology, and environmental regulations in various regions have a positive impact on the green total factor productivity of China's shipbuilding industry, indicating that the strengthening of environmental regulations has a positive "compensation effect" in the shipbuilding industry, supporting the Porter hypothesis. Contrary to traditional research on total factor productivity, the results of this study show that export dependence has a negative impact on China's shipbuilding industry's green total factor productivity. In the dynamic model, the green total factor productivity of the shipbuilding industry and its lag period are highly negatively significant. The logarithm represents the growth of green total factor, indicating that the growth rate of green total factor productivity is inversely proportional to the previous period, and the accumulated green total factor productivity will form driving effect but the growth rate of the promotion gradually slowed down.

The development of China's shipbuilding industry mainly relied on the early investment of a large amount of labor, capital and other production factors. During the prosperous period of the maritime market, it competed with Japan and South Korea on the basis of low labor costs, thereby rising in the international market. With the current rise in domestic labor costs, the increase in uncertainties in international trade and the downturn in the marine market, China's shipbuilding industry has already experienced overcapacity and difficulties in financing. In the marginal theory of macroeconomics, after the fixed assets in production reach stability, the phenomenon of diminishing returns in production scale occurs, and the marginal amount of production will be less than the marginal amount of input.

Ship exports have a negative impact on green total factor productivity while driving the development of China's ships. Looking back at the development of the world's shipbuilding industry, the industry has shifted from the United Kingdom to European countries to today's three East Asian countries and gradually extended to Southeast Asian countries. "Pollution refuge The phenomenon of “all” always exists in the shipbuilding industry. In addition, although China has a long history of shipbuilding, the time when the Chinese shipbuilding industry began to lag behind the developed countries, so that the current Chinese shipbuilding industry is mainly concentrated on dry bulk ships and container ships and other low-value ship types, pulling down Green total factor productivity.

The empirical results show that the increase in R&D investment can promote technological progress and drive the green total factor productivity of the shipbuilding industry. The tightening of environmental regulations in the international market has stimulated new demands in the shipbuilding industry. Green technology research and development and application in the shipbuilding industry have considerable potential. The demand for clean energy and pollution treatment technologies in the ship production process is very urgent. Green technology innovation is the key to the transformation and upgrading of China's shipbuilding industry, and also the direction and focus of the policy of the shipbuilding industry.

CHAPTER 6: CONCLUSION AND POLICY IMPLICATION

The shipbuilding industry has a very long history in China, and the treasure ship that Zheng He sailed to the west marked the heyday of China's shipbuilding industry. In the early period of reform and opening up, the country concentrated human, material and financial resources to develop the basis of the shipbuilding industry and actively expanded the international market. Since the new period, the shipbuilding industry has entered a period of rapid development, showing a rapid development momentum. China has been able to build ships that comply with international regulations and sail in the world waters. At the same time, the quality of the development of China's shipbuilding industry has been questioned by some scholars. Problems such as excessive energy input, low production efficiency, and environmental pollution emissions have attracted the attention of industry and academic researchers. At present, problems such as rising labor prices, a declining marine economy, reduced demand in the international ship market, overcapacity, and difficulties in financing pose huge challenges to the development of the shipbuilding industry. Therefore, under the dual pressure of tightening environmental regulations and sluggish market, China's shipbuilding industry's transformation to achieve sustainable development is an important task at present.

Taking green total factor productivity as the focus point, studying the efficiency evaluation of China's shipbuilding industry under environmental regulation helps to understand the relationship between environmental regulation and the development of the shipbuilding industry, find the key factors for achieving the sustainable development of the Chinese shipbuilding industry, and then take effective countermeasures. Promote the improvement of the international competitiveness of the shipbuilding industry, taking ecological and environmental protection into account.

6.1 CONCLUSION

Based on data from 15 regions of China's shipbuilding industry from 2004 to 2015, the ML index of data envelopment analysis was used to conduct a research on the green total factor productivity of the Chinese shipbuilding industry. The direction distance function was used to decompose the green technical efficiency and technical progress. The indicators were compared and analyzed, and the absolute β convergence test model was used to explore the differences in the growth of green total factor productivity of the shipbuilding industry in various regions of China. Another focus of this study is to dig deeper into the influencing factors of green total factor productivity, use econometric theory to construct a dynamic panel regression model, and use Stata software to perform regression analysis on the impact of environmental regulations on the green total factor productivity of China's shipbuilding industry. The main conclusions are as follows:

(1) The green total factor productivity of China's shipbuilding industry is basically at the forefront of green production and has obvious convergence characteristics. The region with the highest green total factor productivity of the shipbuilding industry is Hunan. The average green total factor productivity of the shipbuilding industry is lower than the average traditional total factor productivity. The combination of green technological progress and green technical efficiency has promoted the green total factor productivity of the Chinese shipbuilding industry, making it generally at the forefront of efficiency, and

basically achieved The growth of the shipping industry and the coordinated development of resources and the environment.

(2) Convergence analysis shows that the development of the shipbuilding industry is gradually converging in space and the difference in development is decreasing. The green total factor productivity of the shipbuilding industry tends to be balanced among regions, and there is also a clear "catch-up effect" between the technical efficiency and technological progress of the shipbuilding industry.

(3) The coefficient of environmental regulation on the green total factor productivity of the shipbuilding industry is positive, which brings a significant "compensation effect" to the industrial development and supports the "Porter Hypothesis" theory. It shows that my country's shipbuilding industry is keeping up with the pace of environmental protection at home and abroad, and the environmental regulation system designed in accordance with China's development characteristics is more reasonable.

(4) Technological progress is an important driving force for the development of green total factors of China's shipbuilding industry. In areas with high investment in R&D funds, the green total factor productivity of the shipbuilding industry is also relatively high. National policies to guide the shipbuilding industry from quantitative to qualitative improvement require The main focus is on technological progress. Guided by export policies, shipbuilding industry orders mainly come from foreign shipowners, and domestic outflow of domestic demand has made shipbuilding industry enterprises over-reliant on exports, inhibiting the growth of green total factor productivity.

6.2 POLICY IMPLICATION

Under the dual pressures of fierce market competition and the tightening of international environmental regulations, the empirical research in this paper provides corresponding policy implications for the development of my country's shipbuilding industry and the improvement of the shipbuilding industry's green total factor productivity. In view of the above empirical analysis and conclusions, this chapter will provide development suggestions from four levels: promoting the transformation and upgrading of the shipbuilding industry, promoting technological progress, stimulating domestic demand, and deepening the integration of financial capital and industrial capital.

6. 2. 1 PROMOTE TRANSFORMATION

Relying on the advantages of the system, China's shipbuilding industry has been positioned as a strategic industry in China after the reform and opening up. The relevant policies have continued to increase their support. With the advantages of low land rent, labor costs, and natural resource input, they have achieved rapid growth. However, in recent years, China's labor costs have continued to rise. The strengthening of domestic and foreign environmental regulations has limited the competitiveness of China's shipbuilding industry, and natural resource endowment advantages have gradually been lost. At the same time, the deepening of the International Shipping Alliance and the adjustment of domestic export tax rebate policies have intensified the development difficulties of shipping companies to a certain extent. In the past, the development model of competing for market share in the international market by subsidizing ship exports was actually subsidizing foreign consumption with domestic resources, which was not sustainable in development. At present, the world shipbuilding industry is in the adjustment cycle. The key shipbuilding companies in the world shipbuilding countries have begun to reorganize and merge. China Shipbuilding Industry Group and China Shipbuilding Industry Group have implemented a joint reorganization. South Korea's Hyundai Heavy Industries and Daewoo Shipbuilding have strengthened their alliance and further strengthened their competitiveness in the field of high value-added ships. Global shipbuilding companies are accelerating integration and a new competitive landscape is taking shape. Affected by intensified international trade disputes and frequent geopolitical factors, the demand for new ships is obviously insufficient. In the face of the continuous downturn in the maritime market, competition for production that lacks profitability and competitiveness will damage the development of domestic industries.

Enterprise decision makers should change the concept of development from a quantitative competition to a qualitative transformation. Related industrial policies also need to focus on the research and development and innovation of the shipbuilding industry, and form a perfect shipbuilding industry that develops upstream and downstream in China. Actively responding to the current situation of insufficient market demand, centering on the strategy of maritime power, the Chinese shipbuilding industry can actively expand the blue economic space. Combining the offshore equipment manufacturing industry with tourism, fisheries, deep-sea space development and other fields, broaden various market segments, take the initiative to create demand, form a top-down complete industrial chain, and accelerate the optimization and adjustment of industrial structure.

6.2.2 PROMOTE TECHNOLOGICAL PROGRESS

Empirical research results show that green technology efficiency and green technology progress have jointly promoted the change of green total factor productivity in the shipbuilding industry, among which green technology progress has played a significant role in promoting. This shows that to improve the green total factor productivity of my country's shipbuilding industry needs to promote technological progress. In order to achieve the emission reduction goals of the Paris Agreement, low-carbon fuels will certainly replace traditional fossil energy sources in the future, and safety and environmental protection technologies are the core hotspots for development. Strengthen the research and development of green production technology and the improvement of economical production process, and at the same time increase the research and development of pollution control technology in the shipbuilding process, thereby reducing the cost of compliance with environmental regulations. Actively responding to changing market demands. In recent years, China's key shipbuilding companies have increased their investment in scientific research, and the ship structure has been continuously optimized. New achievements have been made in the research and development of intelligent ships, green and environmentally friendly shipbuilding, luxury cruise ship construction, and high-end scientific research ship construction. There is still a gap with the shipbuilding technology developed countries. Increasing investment in R&D funds and improving the shipyard's operating environment and production efficiency are the fundamental ways to promote technological progress in the shipbuilding industry.

Technological progress also requires high-tech talents as a support. Shipbuilding countries in the world face the problem of labor shortage at various levels, manifested as "difficult to recruit workers, difficult to retain people, expensive labor" and other issues. The annual increase rate of labor costs is 5%

to 10% This has brought tremendous pressure to shipping companies with small profit margins or even losses. The younger generation is reluctant to enter the shipbuilding industry because of the poor working environment of the shipyard and the high risks factor. The fundamental strategy to cope with labor shortage is still on the shipyard's production efficiency, innovative construction models and processes, combined with information tools, and continuous optimization of production design. The government needs to coordinate the integration of production, education and research, increase the income and social status of shipbuilding scientists and technicians, strengthen marine awareness with basic education as the starting point, cultivate a team of talents from universities, and build a scientific research consortium with multiple advantages. Carry out school-enterprise cooperation in the fields of talent training, scientific research, technological innovation, etc., and promote the deep integration of production, education and research.

6.2.3 DEVELOP DOMESTIC DEMAND

Under the premise of being international market-oriented, it is also necessary to pay attention to the domestic ship market. Due to the influence of policy guidance, China’s shipbuilding industry has a greater dependence on exports. At the same time, the emergence of international shipping alliances has greatly enhanced the bargaining power of international shipowners. The shipbuilding industry competitiveness is becoming increasingly fierce. At the same time, China, as one of the largest shipowner countries, has the phenomenon of outflow of domestic shipbuilding orders. In contrast, Japanese shipbuilding companies, with the support of government policies, are closely integrating fishing boat construction with the core industry in the Northeast region. Although the international status of the Japanese shipbuilding industry has declined in recent years, it has attracted a lot of attention due to its excellent product quality and excellent service. Grant loyal customers. The Japanese government also first recognized that industrial alliances are an important way to cope with fierce market competition, and support shipping companies to jointly take orders, cooperate in research and development, unified procurement, and form alliances. Constantly optimizing the main ship types such as bulk carriers is the main development strategy of the current Japanese shipbuilding industry. It consolidates and strengthens the construction advantages in product quality, economic performance, and environmental protection to ensure product competitiveness.

China's shipbuilding industry has a solid foundation with comprehensive comparative advantages such as labor, technology, and capital. It has formed a large market influence in the major ship types such as tankers, bulk carriers, and container ships. High-end products have corresponding construction capabilities, technical and management levels. It is also gradually improving and is moving from the world's shipbuilding power to the world's shipbuilding power. However, in the short term, the deep-seated problem of "difficult to take orders" in the international market is still outstanding. Facing the fiercely competitive market, China's shipbuilding industry should work to boost the domestic ship market demand, reduce the periodic impact of the marine market, and achieve sustainable development.

6.2.4 INTEGRATION OF FINANCIAL CAPITAL AND INDUSTRY CAPITAL

As a heavy-asset enterprise, the shipbuilding industry can effectively solve the problem of "financing difficult", which directly determines the survival of shipbuilding enterprises. Affected by the financial crisis, banks have tightened the issuance of guarantees for shipping companies. Even some key shipping companies with good operating conditions, excellent product quality, and strong international competitiveness have also suffered from capital chain cuts in orders and production operations. problem. What's more, some financial institutions pursue a "one size fits all" policy, reducing the total amount of guarantees for shipping companies, not issuing guarantees for ship export advances, or intentionally extending the opening period.

Faced with the problem of "financing difficulties", on the one hand, the government needs to provide financial policy support. It is recommended that financial institutions can implement differentiated credit policies and adopt "one enterprise, one enterprise" for some key shipping companies with good operating conditions and high product technology content. The "policy" approval method provides targeted financing support to the shipping companies that need guarantees. At the same time, further strengthen the information communication between financial institutions and shipping companies to improve the accuracy of financial services. On the other hand, in the face of the world financial market, listed companies in the shipbuilding industry can increase the conversion rate of asset securities and deepen the integration of financial capital and corporate capital. For example, cooperate with trusts and insurance companies to comprehensively improve financing capabilities, develop financing services through the entire shipping industry chain, and develop supply chain finance in combination with innovative models such as blockchain.

6.3 PROSPECT

This paper uses data envelopment analysis to comprehensively evaluate the green total factor productivity of China's shipbuilding industry, and explores the influencing factors of green total factor productivity through a dynamic regression model. However, limited by the depth and breadth of the author's theoretical knowledge and the accuracy of the empirical method, this study still has deficiencies. The consideration of environmental factors to study the total factor productivity of China's shipbuilding industry needs to be further deepened.

First of all, the current research is limited to the Chinese shipbuilding industry. However, the international ship market has formed a three-legged form of China, Japan and South Korea. In a domestic comparison of regional environmental regulations, the impact on total factor productivity has been relatively limited. Future research can consider the differences in environmental policies of different countries and conduct in-depth research on the issue of green total factor productivity in the shipbuilding industry. Secondly, the evaluation of environmental performance cannot rely on a small number of indicators. It is necessary to develop more comprehensive environmental comprehensive agency variables to overcome the research bias caused by the subjectivity of indicator selection. A scientific environmental index system can also provide detailed recommendations to environmental policy makers, making research more valuable. Finally, how the policy design and implementation of green total factor productivity affect the green total factor productivity of the shipbuilding industry requires more detailed research, empirical analysis from the details of environmental policy design, and explores the important impact of environmental regulation on green total factor productivity.

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