

¹ Tianchao Guan^{2,*} Zhehui Zhang^{3,*} Di Xu⁴ Peng Cai

Data-driven study of container handling charges in coastline ports of China



Abstract: - With the rapid development of networking and digitization, the data generated by various industries has shown exponential growth. The seaport industry is the fundamental industry to support the operation of the national economy, and undertakes the vast majority of China's foreign trade, materials, and coal transport along the sea. In response to some of China's major seaports of container handling charges for different extent of the upward event. In this paper, by researching the main seaports of China's coastal ports, we have obtained the level of container handling charge, and operating cost of container section. Meanwhile, this paper combines the reform history of China's port container charging policy and the comparison of domestic and foreign charging levels to discover the cost structure of the container handling charges. It establishes the benchmark for the optimization of the container handling charges. Utilizing data analysis related to production and operations, this paper proposes an optimization method of container handling charges based on the cost analysis of container port companies with macro and micro coupling and puts forward effective suggestions on this basis. This paper suggests the establishment of a mechanism for regulating container handling charges. It also proposes a mechanism for monitoring and regular announcement of container costs.

Keywords: Waterborne transportation; Container transport; Data analysis; Container handling charges; Optimization.

I. INTRODUCTION

Currently, whether it is the formulation of national macro policy, or business strategy decision-making and the optimal operation of industrial production, all rely more and more on the monitoring and analysis of data. Data analysis is an important technical approach to explore the intrinsic value of data, and data analysis methods have become a common basic science problem in many interdisciplinary fields. The seaport industry is a fundamental industry to secure the operation of the national economy, undertaking more than 90% of China's foreign trade and material, 98% of imported iron ore, 90% of imported crude oil, 98% of imported grains, and more than 800 million tons of coal for transfer along the sea shore. Since the beginning of its creation, containerized transport has gradually developed into an advanced and modern transport mode, which enables remote "door-to-door" transport services for owners ^[1]. Commencing on January 1, 2022, the container handling charge of some major ports along the Chinese seaboard has been adjusted upward to a varying degree, and this initiative has attracted widespread attention from both the state and port enterprises. According to the Ministry of Transport and the National Development and Reform Commission jointly published the "Notice on the Revision and Publication of the Port Charges Billing Methods" ^[2], port operators can independently regulate the charging standard of the port operation package charges according to the market supply and demand, production and operation costs as well as the service content, which is market behavior. Recently, the operating costs of port operators have been rising along with the social price increases and the requirements of labor, raw materials environmental protection, etc. Along with the additional costs brought by the prevention and control of sudden epidemics, port operators have been facing the dilemma of declining business operating income and investment returns, and the high-quality development of ports has been challenged. Meanwhile, the increase in container handling charges has generated widespread concern in the industry about the reasonable magnitude of the charges adjustment and the basis of the calculation. Nowadays, domestic and foreign studies on container handling charges in ports mainly focus on the following aspects.

One is the study of the formation conditions and influencing factors of port handling charges. They analyzed the formation conditions of the charges from historical factors, the composition of the charges, the economic level, and other dimensions, and then analyzed the differences between the container port handling charges of different port enterprises, and finally obtained the influencing factors of the charges. YAP W and LAM J utilized container data from 1970 to 2001 to discover the dependencies of ports within the East Asia regional area. They found that Hong Kong has better intra-regional dependencies ^[3]. They analyze the influential factors in the port

¹ Centre for Economics, Policy and Development Strategy, China Waterborne Transport Research Institute, Beijing 100088, China

² Centre for Economics, Policy and Development Strategy, China Waterborne Transport Research Institute, Beijing 100088, China

³ Centre for Economics, Policy and Development Strategy, China Waterborne Transport Research Institute, Beijing 100088, China

⁴ Centre for Economics, Policy and Development Strategy, China Waterborne Transport Research Institute, Beijing 100088, China

*Corresponding author: Zhehui Zhang, Di Xu

Copyright © JES 2024 on-line : journal.esrgroups.org

infrastructure tariff formulation process from the perspective of port infrastructure tariffs using survey data and provide implications for port authorities, management, and stakeholders ^[4]. In addition, through a regional survey of shipping companies and owners, they found that the determining factors of competition between Chinese and Korean ports are port service, hinterland condition, availability, convenience, logistics cost, regional center, and connectivity. logistics cost, regional center, and connectivity ^[5]. On the other hand, it is a study of the management mechanism and price mechanism of ports. They qualitatively analyze the problems related to the current management mechanism and price mechanism of China's ports from the macro level. Sui et al extrapolate the development trend of port prices from the port price development mechanism and Xie X has analyzed the economics of port reform charges ^[6-7]. In the last one, scholars quantitatively analyze the pricing strategy of the port handling package charge at the micro level. Zheng et al. analyze the issue of social welfare in ports by considering the impact of tariffs and other factors on the generalized price under the perspective of port regulation ^[8]. Dong constructs a competitive service pricing model for ports based on the key influencing factors, focusing on the comparison of Bergwald's competitive and compensatory pricing strategies and their profitability differences, and conducts a multifactor sensitivity analysis ^[9]. Guo et al. compared prices and profits for ports that operate both bulk and containerized cargoes, using the methodology of the Gounod game, taking into account the cost of congestion ^[10]. Yang et al. utilize the Hotelling model in game theory to analyze the impact of service pricing on port market share and revenue ^[11].

According to existing research, it is found that the studies on container handling charges focus on price influencing factors, price mechanisms, and price strategies, and have not taken a systematic approach to optimize container handling charges under the interaction of macro-conditions (e.g., residents' income, energy consumption) and micro-conditions (e.g., port operational efficiency). In the meantime, the existing research emphasizes more on the exploration of charging theory and does not fully consider the actual production and operation data of port companies and the influence of port container charging policy. Therefore, this paper will consider the impact of production and operation data and port container charging policy to study container handling charges. And this paper by researching the main coastal ports of China's foreign trade 20-foot container heavy container handling charges, grasped the main coastal ports of China's foreign trade 20-foot container handling charges level, container plate operating costs, and other status quo and its cost components, combined with China's ports container charge policy reform history and the comparison of domestic and foreign charge level, the use of the combination of macro-micro-analysis methods for China's coastal ports of container handling charges to launch a comprehensive study of the problem.

II. REFORM HISTORY AND DEVELOPMENT STATUS OF CHINA'S PORT CONTAINER CHARGE POLICY

In this section, we describe the current situation of container handling charges in coastline ports with policy texts and accounting data. At first, we understand the development history of container handling charges through the container charge policy, and make clear that it has the attribute of market regulation. Next, through the comparative study with the domestic and foreign charge level and the operating benefits, it is realized that the level of container handling charges in China is lower than the market level. And finally, from the perspective of transportation cost, it is noticed that container handling charges account for a very low percentage in the logistics cost. Through a combination of text analysis ^[18], comparative analysis, profit analysis and percentage analysis, we have clarified that the issue of container handling charges is a market behavior and is below the domestic and international market levels.

A. Reform History of China's Port Container Charge Policy

To meet the needs of economic and social development, China's ports have realized the transformation from a planned economy to a socialist market economy with Chinese characteristics. After the founding of New China, a port management system was initially constructed under the planned economy with centralized control and the unification of government and enterprises; the State was the single main body of port investment and operation, and charges for port loading and unloading operations were priced by the Government and set up separately according to the operation segment. The port management system of the planned economy era is not prone to stimulate the enthusiasm of local city governments to develop ports, from 1984 to 1989, the former Ministry of Transportation directly under the 14 coastal ports, 26 key ports on the Yangtze River trunk line of the Ministry of Transportation and the local government to implement the "dual leadership, the local authorities" management system. The State Council promulgated the Interim Provisions on Preferential Treatment for Sino-foreign Joint Venture Construction of Ports and Terminals (repealed in 2008), which stipulates that "the loading and unloading

fees and other rate standards of the terminals constructed by the joint venture shall be determined by the enterprise and reported to the competent department in charge of the enterprise and the local price department for the record", which officially opened the process of marketization of China's ports, but at this time, the container handling charges had not been subdivided according to the type of cargo and had not formed certain industry guidelines^[12]. Since the WTO accession, for the development of ports, the State Council has implemented the port all decentralized local management, the implementation of the separation of government and enterprises, port enterprises no longer bear the administrative functions, to become a self-managed, self-sustaining legal entity. The Ministry of Transport promulgated the Rules on Port Charges of the Ministry of Transport (Domestic Trade Section) in 2005, which stipulates that domestic trade goods and containers are subject to lump-sum billing for loading and unloading and other labor operations at ports and that market-adjusted prices are implemented^[13]. The Ministry of Transport and the National Development and Reform Commission promulgated the Circular on Issues Relating to the Liberalization of Competitive Service Charges in Ports in 2014, which stipulates that labor charges for container and bulk cargo handling operations and international passenger terminal operations shall be changed from separate charges for each operation to lump-sum charges and that market-adjusted prices shall be implemented^[14]. From then on, China's port charges for domestic and foreign trade container loading and unloading operations, are adopted in the form of operating charges and the implementation of market-adjusted prices.

To further clean up and standardize port operation and service charges, the Ministry of Transport and the National Development and Reform Commission jointly issued the Regulations for the Billing of Port Charges in 2015, which adjusted and optimized the policy system for port charges based on the principle of "reducing, merging and lowering charges", and was modified twice, in 2017 and 2019. The revised Regulations on Port Charges Billing in 2019 stipulates in Article 3 that Port charges include operation and service charges that are subject to government pricing, government-guided pricing, and market-adjusted pricing, and port charges that are subject to market-adjusted pricing include port operation lump-sum charges, depot use charges, vessel supply service charges, vessel pollutant reception and treatment service charges, cargo handling service charges^[2]. At this point, China's port container handling charges have formed a relatively comprehensive mechanism to make clear provisions for the port charges project.

B. Comparative Analysis of China's Port Container Handling Charges with Domestic and Foreign Countries

As the standardization level of container handling operations in ports is relatively high, and the loading and unloading processes adopted by ports within and outside the country are similar and comparable, this paper compares the container handling charges of the world's major mainline ports with those of foreign trade 20-foot containers as an example of the heavy container handling charges (shown in Figure 1). It is clear from Figure 1 that the foreign trade 20-foot container heavy container handling charges of Shenzhen and Hong Kong ports are in the range of RMB 800-934, which is relatively high in China. Nevertheless, most of the container handling charges of other mainline ports along the coastal areas of China are in the range of 470-583 RMB. There is a discrepancy between this charging range and that of the Pusan, Kaohsiung, and Singapore ports for foreign trade 20-foot containers with heavy containers (charging range of RMB 630-750), and it is 3-4 times lower than that of the typical ports in Europe and America (charging range of RMB 1,180-2,024). Concurrently, although port enterprises such as Ningbo Zhoushan Port, Guangzhou Port, and Xiamen Port have already increased their containerized port handling charges by about 10% at the beginning of 2022, they are also still lower than the level of containerized port handling charges of China's neighboring Pusan Port, Kaohsiung Port, and Singapore Port. By comparison, it can be seen that the charging level of the container handling charge for coastal ports in China is at a relatively low level.

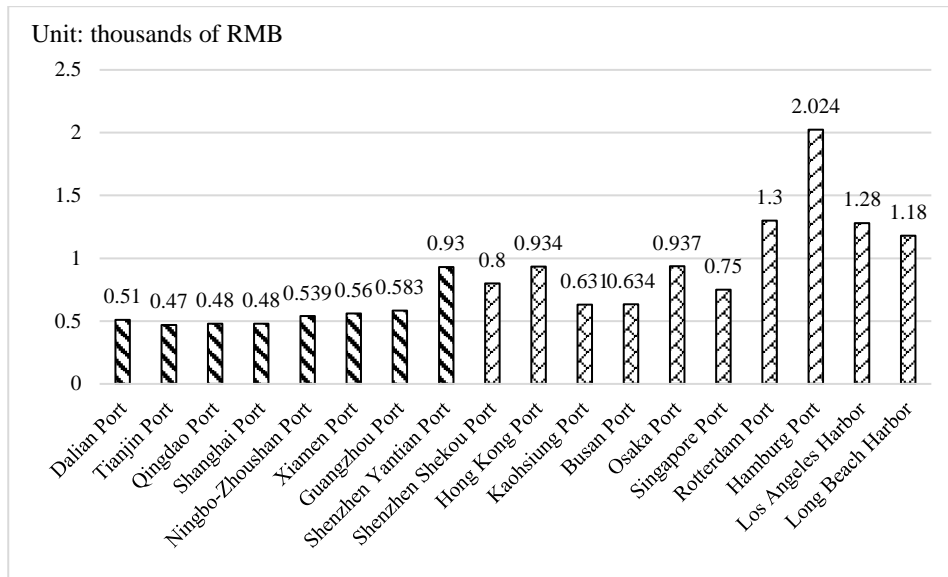


Figure 1: Ranking of Container Handling Package Charges in the World's Major Ports in 2022

C. The Operating Benefits Analysis of China's Major Port Operators

The port is a fundamental industry of the national economy, with the attributes of competitiveness and public welfare. With the consolidation of port resources, the scale of port enterprises has been expanding, and the competitiveness of the port industry has been enhanced, but it has not had a significant impact on the improvement of the benefits of port operators. This paper analyzed the return on net assets (ROA) of listed companies in Shanghai and Shenzhen A-share wharves by collecting their financial data and found that the average value of ROA in the port industry (average value of 7.63%) is lower than the average value of ROA for all companies in Shanghai and Shenzhen A-shares (market average value of 8.64%) for a long period, as shown in Figure 2. Also, this paper gathered the financial data of 17 listed port companies in China's mainland to analyze the return on net assets. From the analysis, it can be seen that among the 17 listed port companies in China's mainland, there are only 6 companies with a return on net assets higher than 8.0%, among which, Shanghai Port Group, has the highest profit of China's listed port companies, has 15.68% return on net assets. And yet, 60% of SIPG's profits come from investment income from investment banking, real estate, shipping, etc. The port operations segment did not generate excess profits (as shown in Figure 3). As a result, the operating benefits of our major port operators are generally lower than the market average.

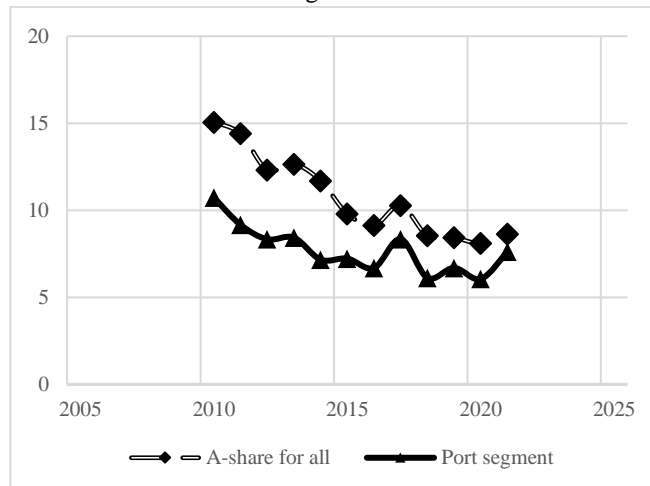


Figure 2: ROA for all A-share and port sectors listed companies

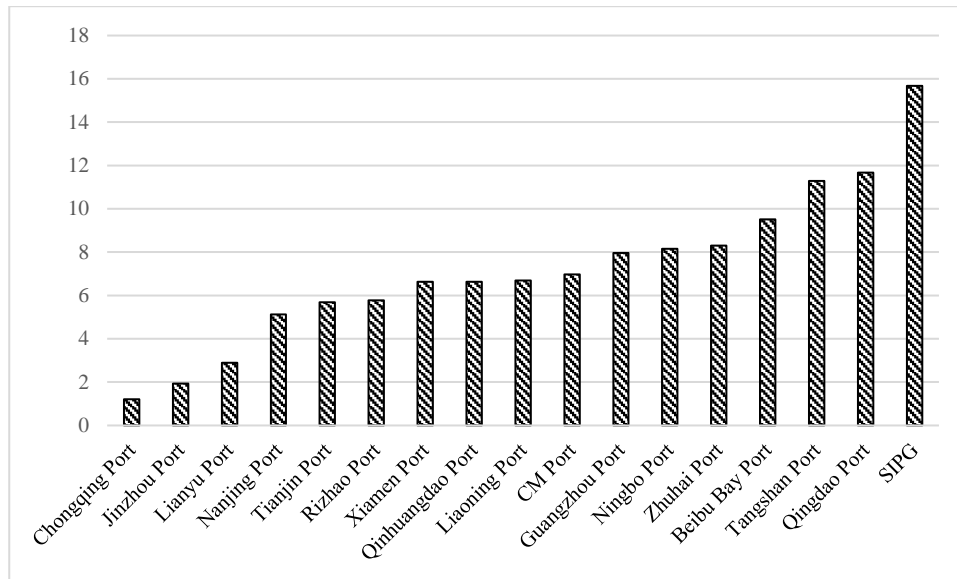


Figure 3: ROA of Mainland China's public-listed port companies in 2021 (Data from Wind)

D. The Proportion Analysis of China's Port Container Handling Charges to Shipping Costs

Generally, the determination and variation of shipping costs depend on the supply and demand for transport services. In practice, the maritime transport system is composed of three subsystems: port inland assembly and evacuation transport, port transshipment, and ship transport ^[15], and the efficiency of port transshipment has a direct impact on the efficiency of ship turnover and the level of capacity supply. If port transshipment is operating at full capacity, the quality and efficiency of port services will be affected, causing an increase in the number of vessel stoppages, which in turn will have an impact on shipping costs. Taking China's exports to the west coast of the United States and Western Europe as an example, according to the data calculated in July 2020 when shipping costs had not yet risen sharply, the proportion of container handling charges of port enterprises to the total cost of logistics was 2.38% and 4.63% respectively ^[16]. Maritime shipping costs rose sharply after July 2020, and while maritime freight rates were running at high levels, the proportion of container handling charges to total logistics costs and expenses for port enterprises fell to less than 1 percent. Therefore, the port containerization charges account for a very low proportion of the total cost of logistics, only a very small part of the maritime freight.

III. ANALYZING THE CONTAINER HANDLING CHARGES IN CHINA'S PORTS ACCORDING TO DATA RELEVANT TO PRODUCTION AND OPERATION

From the part 2, it can be seen that although China's port container handling charges belong to the market price adjustment, their level of charges is in a low position, and the operating efficiency of port operators is also lower than the average level of the market. To explore the reasonable level of the port container handling charges, this section will analyze the accounting data in the past five years of the port operators and the statistical data in the past four years such as income and energy consumption. The weighting analysis method can obtain the proportion of expenses in the port container handling charge, while the polynomial fitting analysis is conducive to stabilizing the port container handling charge, facilitating the national macro-control, and promoting the establishment of a monitoring mechanism for the port container handling charge.

A. Weighted Analysis of China's Container Handling Charges According to the Accounting Data

This paper collects the accounting data of container port companies in Shanghai Port, Ningbo Zhoushan Port, Qingdao Port, Shenzhen Port, Guangzhou Port, Tianjin Port, Dalian Port, Xiamen Port, and other major ports in the past five years, and combines the throughput of each port in the past year using the weighted analysis method ^[19] to obtain the composition of the total cost of the container port company and the percentage of each cost in the total costs. The Company's total operating costs consist of three main categories: operating costs, five expenses, and other costs, such as fuel costs. Of these, operating costs mainly comprise production operating expenses (including labor outsourcing) and depreciation and amortization expenses (mainly referring to infrastructure depreciation); the five expenses comprise selling expenses, administrative expenses, research and development expenses (including employee compensation, depreciation and amortization of intangibles, etc.),

finance costs and taxes and surcharges. Using a_i to denote the various costs and expenses at the micro-level, it can be seen through Table 1 that the five costs account for 19.40% of the total costs and expenses, other costs such as fuel costs account for 27.32% of the total costs, and expenses, and the rest of them are the share of operating costs. The percentage of operating costs is 24.01% for production operating expenses, where labor outsourcing is the higher type of cost in production operating expenses and 29.26% for infrastructure depreciation and amortization.

Table 1: Composition and percentage of each cost and expense

a_i	Classify costs and expenses	Weighting approach	
a_1	five expenses and other costs	19.41%	
a_2 operating costs	production operating expenses (24.01%)	Labor Costs	8.23%
		Labor Outsourcing	15.78%
	Infrastructure depreciation and amortization	29.26%	
a_3	Other costs such as fuel costs	27.32%	
	Total	100%	

B. Polynomial Fitting Analysis of China's Container Handling Charges According to Statistical Data

Through the weighted method, it can be seen that the classification of the total cost of expenses of port enterprises, in addition to belonging to the internal cost classification of the company, also corresponds to the external macro factors such as residents' income, energy consumption, etc., which shows that the port charges are subject to the internal cost constraints of the company and the external macro factors together. To investigate its mechanism of operation, this paper collects statistical yearbook data from the National Bureau of Statistics from 2017 to 2020 [17] and analyzes the changing patterns of national per capita income, average urban residents' wages by industry, and energy consumption by industry. The relationship between micro and macro factors was obtained using the polynomial fitting method [20]. The changes in average income per capita by industry and energy consumption by industry are consistent with a polynomial form with R^2 -mean being equal to one. The trend line of changes in average income per capita by industry is expressed as $y = -0.0027x^4 + 0.0291x^3 - 0.113x^2 + 0.1809x - 0.01$, and the trend line of changes in energy consumption as $y = 0.0071x^4 - 0.0894x^3 + 0.3842x^2 - 0.6484x + 0.4028$, where x denotes the unit of time (years) and y denotes the proportion of change with time. And the change in the average wage of urban residents by industry is consistent with a polynomial trend with R^2 -mean being equal to 0.9876, expressed as $y = -0.0137x^3 + 0.1276x^2 - 0.3777x + 0.4497$, where x denotes the unit of time (years) and y denotes the proportion of change with time. Thus, the changes in the national per capita income and energy consumption by industry are consistent with the mathematical properties of the standard normal distribution, and at the same time, the rate of change in the national per capita income is higher than the rate of change in energy consumption by industry, as shown in Figure 4.

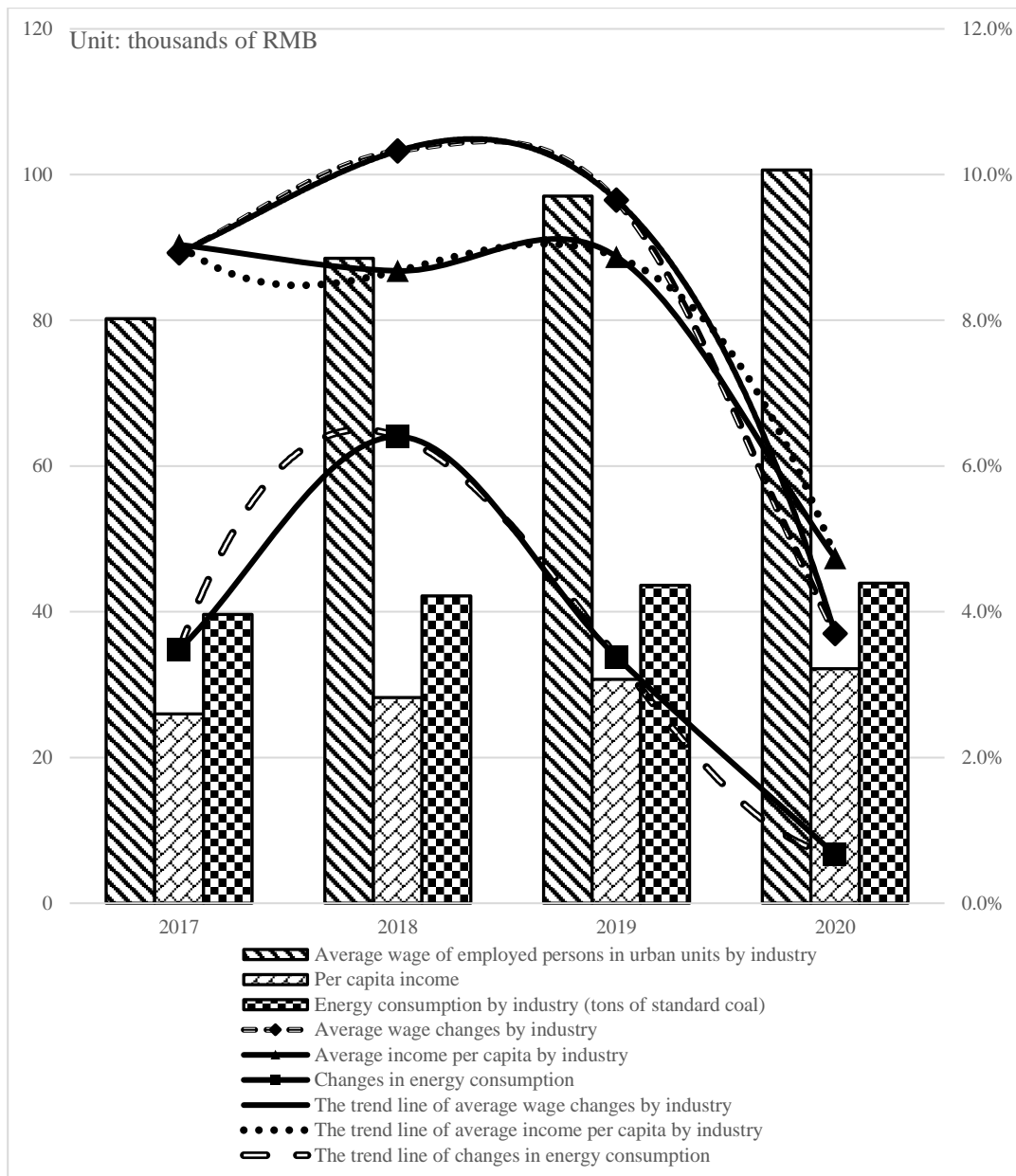


Figure 4: Percentage change in per capita income and energy consumption by Industry from 2017 to 2020

Together with the micro-analysis, it is known that there is a correlation between the payment of production and operation costs paid by port enterprises and the average wage level of employees in the industry and the level of per capita income of national residents, and there is also a correlation between other costs paid by port enterprises, such as fuel costs, and changes in energy consumption in the industry. Thus, the total cost and expense of port enterprises in the production operation costs are related to the average income level of residents, and other costs and expenses, such as fuel costs, are related to energy consumption, so the total cost and expense of port enterprises is about the result of the joint action of micro factors and macro factors. Based on this, the calculation method of the change percentage of total cost and expense based on the macro-micro coupling of market adjustment price is proposed, as shown in equation (1).

$$\Delta TC = \sum_{i,j} a_i c_j (I, E) \quad (i, j = 1 \dots 4) \tag{1}$$

Where ΔTC denotes the percentage change in total cost, a_i denotes the various costs and expenses at the micro-level, c_j denotes the various costs and expenses at the macro-level, denotes the change percentage of average wage by industry, E denotes the change percentage of energy consumption by industry.

According to the calculation of the change percentage of the average cost and expense of 20-foot container heavy lift container from 2017 to 2021 (as shown in Figure 5), the total cost and expense of 20-foot container heavy lift container increased by 8.63%, 6.00%, 4.01%, 1.24%, and 5.49% year-on-year from 2017-2021,

respectively, and its cumulative growth (25.82%) is higher than the growth of CPI and PPI [17], as shown in Table 2. Depending on the reality of the data, it can be predicted that the expression of its trend line is $y = 0.004x^4 - 0.0429x^3 + 0.1593x^2 - 0.2649x + 0.2308$, where x denotes the unit of time (years) and y represents the percentage change with time. This function is consistent with the R^2 -mean being equal to one.

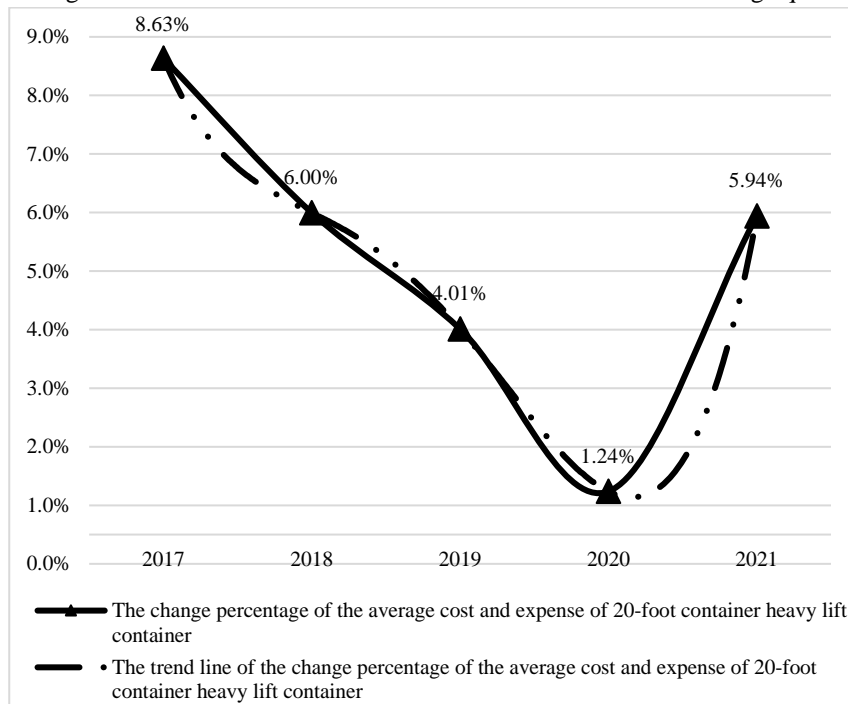


Figure 5: The change percentage and change trend of the average cost and expense of a 20-foot container heavy container from 2017 to 2021

Table 2: Composition of total container cost and expense with CPI and PPI from 2017 to 2021

Time	2017	2018	2019	2020	2021	Cumulative
CPI increase	1.6%	2.1%	2.9%	2.5%	0.9%	10.0%
PPI increase	6.3%	3.5%	-0.32%	-1.8%	8.1%	15.8%
Total cost increase	8.63%	6.00%	4.01%	1.24%	5.94%	25.82%

IV. CONCLUSIONS AND RECOMMENDATIONS

With the development of advanced technology, the port multi-source spatial and temporal data has increased dramatically, only through the traditional way is unable to meet the demand for scientific pricing of container handling charges. The paper collects production and operation data and statistical data from several enterprises, and uses the method of data analysis to solve the practical problems of ports. In this paper, starting from the actual problems of port enterprises, combined with the reform history of China's port container charge policy, through texts analysis, we get that China's port enterprise's container handling charges are about the results of the joint role of micro-factors and macro-factors. Based on this, the paper puts forward the macro-micro coupling of charges based on the cost analysis of container port enterprises, and uses empirical data to get the cumulative increase in the total cost of 20-foot container heavy container charges is higher than the cumulative growth of CPI, PPI, so the macro-micro coupling of optimization of the price method of the industry has a certain degree of significance of the guide. Also, two recommendations were made to inform subsequent developments. One is the establishment of a mechanism to regulate port handling charges. According to the analysis of cost fluctuations, neighboring ports, and enterprise interests, the port enterprises are guided to formulate charges based on operating costs and market conditions and are allowed to adjust their charges by adopting annual upward adjustments that do not exceed the CPI. Container port operates a filing mechanism whereby the highest charges (basic charges) and the lowest charges (preferential charges) for the following year are filed with the relevant government departments in December of each year. Also, for the international transshipment business of containers, the enterprises will set their prices according to the market competition. The second is the setting up of a mechanism for the monitoring and regular release of port container costs and expenses. We support the third party to carry out the monitoring and analysis of port container costs and expenses and to release them, continuously tracking

the changes in the prices and costs of the charges of our neighboring ports, and evaluating and analyzing the level of port operations charges regularly in terms of the benefits of the enterprises in the industry, as well as comparing the level of such charges with those of the neighboring ports.

REFERENCES

- [1] DAI Q. The Optimization of port hinterland container intermodal transportation network with consideration of carbon emissions. Wuhan University of Technology for the Doctor's Degree, 2021.
- [2] Ministry of Transport of the People's Republic of China. Measures for the Accounting of Port Charges, 2019. https://www.mot.gov.cn/zhengcejiedu/gksfjfbf_xdjd/.
- [3] YAP W, LAM J. Competition dynamics between container ports in East Asia. *Transportation Research Part A: Policy and Practice*, 2006, 40(1): 35-51.
- [4] BANDARA Y M, NGUYEN H O. Influential factors in port infrastructure tariff formulation, implementation and revision. *Transportation Research Part A: Policy and Practice*, 2016(85): 220-232.
- [5] YEO G T, ROE M, DINWOODIE J. Evaluating the competitiveness of container ports in Korea and China. *Transportation Research Part A: Policy and Practice*, 2008, 42(6): 910-921.
- [6] SUI L, XU P, YU J, et al. China's port price formation mechanism and development trend. *Shipping Management*, 2015, 37(1): 14-18.
- [7] XIE X. Economic analysis of port tariff reform. *China Ports*, 2015(9):13-15.
- [8] ZHENG S Y, NEGENBORN R R. Centralization or decentralization: A comparative analysis of port regulation modes. *Transportation Research Part E: Logistics and Transportation Review*, 2014(69): 21-40.
- [9] DONG G. Pricing strategy of port competitive service based on market regulation. *Journal of Transportation Systems Engineering and Information Technology*, 2019, (02): 1-6.
- [10] GUO L B, LI J, XING W. Port co-opetition research in bulk and container businesses. *Journal of Transportation Systems Engineering and Information Technology*, 2017, 17(2): 189-196.
- [11] LU Hanyu, YANG Bin. Service pricing strategy of Hong Kong Port and Shanghai Port based on Hotelling model. *Journal of Shanghai Maritime University*, 2017, 38(3): 61-66.
- [12] State Council of the People's Republic of China Interim Provisions on Preferential Treatment for Sino-Foreign Joint Venture Construction of Ports and Terminals.1985.
- [13] Ministry of Transport of the People's Republic of China. Measures for the Accounting of Port Charges (Domestic trade segment).2005.
- [14] Announcement on Issues Related to the Liberalization of Charges for Competitive Port Services.2014.
- [15] HAN J W. Inland container transport system development research based on coordination theory. Beijing jiaotong University for the Doctor's Degree, 2015.
- [16] ZHANG Z H. Optimizing doing-business environment of shipping and ports. Wuhan University of Technology Publication, 2020:88-93.
- [17] National Bureau of Statistics of China. National Yearbook of Statistical Reports (NYSR). <http://www.stats.gov.cn/sj/tjgb/ndtjgb/>
- [18] Junhui Zhang, etc., Application of Traffic Accident Information Text Processing Technology Based on LDA Topic Model. *Ekoloji*, 2019
- [19] Chen, J.; Li, G.; Wen, J. Yan. An expert weight determination method based on data analysis//Professional Committee of System Simulation, Chinese Society of Automation, and Professional Committee of Simulation Technology Application, Chinese Society of System Simulation. Proceedings of the 18th China Academic Annual Conference on System Simulation Technology and its Applications (18th CCSSTA 2017). University of Science and Technology of China Press,2017:314-317.
- [20] Li Yupeng;Cheng Yuan;Ni Yongbo;Zhang Na.Assessment of product resilience towards the changing customer requirements.*Journal of Engineering Design*,2023(8).DOI:10.1080/09544828.2023.2239484.