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A PERFORMANCE EVALUATION MODEL FOR SHIPPING LINE IN TAIWAN AN APLLICATION OF DATA ENVELOPMENT ANALYS

ĐÁNH GIÁ HIỆU QUẢ CÁC HÃNG TÀU ĐÀI LOAN SỬ DỤNG PHƯƠNG PHÁP PHÂN TÍCH BAO DỮ LIỆU

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Abstract

This paper attempts to evaluate efficiency for shipping industry with financial indicators. Data on the industry were obtained from Taiwan Market. It analysing the performance of the shipping line firms during the period of 2020-2023, the DEA was used to determine that achieved the highest performance in terms of the input and output variables.

This study aims to quantify the shipping industry's operational efficiency and to provide an overview of the state of operations so that managers and entrepreneurs can enhance their performance. We use data envelopment analysis (DEA) to calculate the operating efficiency 11 shipping companies in this paper. According to the result, Yang Ming, U-Ming, and Franbo Lines are the shipping lines with the highest average productivity. These three brands will continue to have the highest average productivity in the industry. This paper can be a beneficial reference to shipping line firms for the policymakers, investors, development, and shipping line management.

Keywords: *DEA, Taiwan Logistics.*

Tóm tắt

Nghiên cứu dựa vào các chỉ số tài chính đánh giá hiệu quả các công ty hãng tàu lớn tại Đài Loan. Nghiên cứu sử dụng mô hình bao dữ liệu đánh giá hiệu quả các công với các chỉ số đầu vào và các chỉ số đầu ra trong giai đoạn từ 2020 đến 2023. Bài báo đưa đến cái nhìn tổng quan về 11 hãng tàu lớn tại Đài Loan, giúp các nhà quản lý đánh giá được hiệu quả kinh doanh tại doanh nghiệp. Kết quả nghiên cứu thì các hãng tàu như Yang Minh, U-Ming, and Franbo Lines đạt hiệu quả kinh doanh cao. Bài báo là tài liệu tham khảo hữu ích cho các công ty vận chuyển đường biển, các nhà hoạch định chính sách, nhà đầu tư, phát triển và quản lý cải thiện hiểu quả tại các công ty vận chuyển.

Từ khóa: *DEA, Logistics Đài Loan.*

1. Introduction

Companies in Taiwan account for three of the top 20 largest container cargo shipping enterprises in the world. According to calculations by the Australian Strategic Policy Institute, a think tank, roughly a third of global shipping - and therefore almost one-quarter of the entire global trade by volume -passed through these waters. With Japan and Singapore, Taiwan connect two of the most critical destinations for the global economy. Two of Taiwan's own ports, Kaohsiung and Taipei, are among the largest in the world. Taiwanese ship operators, notably Evergreen, Yang Ming Marine control more than 10% of global container capacity.

Data envelopment analysis (DEA) is an effective method for evaluating the performance of firms in the same industry. DEA use input and output data of firms to asses the performance of each firm relative to others in the group. The DEA approach can be used to solve the above mentioned weight assignment problems.

There are numerous large shipping businesses in Taiwan. Shipping makes up more than 90% of the company's revenue, and it is one of its primary operations along with shipping agency, ship and container trading, port container terminal operating, and ship and container renting. Given the unpredictability of greater variations in supply and demand for transportation services, this will be a challenging task. So this study will help managers in shipping lines make decisions for investors in the future and also help companies identify their strengths and weaknesses compared to competitors, thereby formulating appropriate strategies to improve performance.

The paper includes five part. The first section is the introduction. The second part indicate some previous studies related to performance assessment.

2. Literature review

Data Envelopment Analysis is a technique applying in mathematical programming posed by Charnes et al. [1]. Weng - Cheng Lin, et al.[2]. applied the DEA model to evaluate performance of shipping industry. Research findings indicate that taking financial ratios into account can lead to a more thorough performance review of the shipping business. Bing-Lian Liu, et al.[3].used DEA models and Malmquist TFP approach to measure the efficiency of container terminals in mainland China. The three-year average Malmquist TFP index score of 1.125 indicates an improvement in China's container terminal productivity. As a result, mainland China's container ports are more effective at handling the containers of foreign shipping lines than those of domestic shipping lines. Shih-Liang Chao, et al.[4]. applied dynamic network DEA to evaluate the efficiency of container shipping companies CSC' period from 2013 to 2015. Every CSC's division and company efficiency scores are calculated and analyzed. Hong-Oanh Nguyen, et al.[5]. employs bootstrapped DEA to a sample of the 43 biggest ports in Vietnam and contrasts the findings with traditional DEA and stochastic frontier analysis (SFA) findings. The findings demonstrate that although the efficiency scores derived from the three approaches offer consistent and helpful assessments of the ports' efficiency, they diverge considerably. Horng-Jinh Chang and Ling-Chu Liao.[6] applied the data envelopment analysis (DEA) model to estimated performance methods for the ocean freight forwarder. The use of DEA is readily adaptable and expandable to comparable environments for other businesses, in other maritime zones, including the deep sea and the short sea.

Pei Fun Lee, et al. [7]. used the DEA model to evaluate efficiency of logistics companies. The findings indicate that all Malaysian logistics companies that use a data envelopment analysis (DEA) methodology have an operational risk component. In the suggested model, the operational risk capital need component is indicated by the basic indicator approach (BIA). Nguyen - Dai Duong, et al.[8] DEA Malmquist was utilized to conduct an output-oriented CCR and BCC DEA model analysis of the 26 container terminals located in Vietnam.To assess how the productivity of container ports has changed over time, the Malmquist Productivity Index (MP I) was also used. Chia-Nan Wang, et al.[9] used the DEA Malmquist and EMB model for the evaluation of seaport terminal operators. The DEA model assesses the total productivity growth rates of the companies and the EBM to calculate the efficiency inefficiency score of each company. Toshiyuki - Sueyoshi, et al.[10] applied the Data Envelopment Analysis (DEA) to evaluate energy and environment. The study is that technology innovation in engineering and natural science to enhance reduce problems climate change and environment pollutions.

Magdiel A. Agüero-Tobar,et al.[11] used the DEA model to estimate the efficiency of the logistics performance of twelve Chilean containerized port cargo terminals. E. Krmac et al. [12] applied the DEA methodology to evaluate port performance. The result of the study is important for researchers as well as port managers and policy markers for analyzing future port performance.Rujia Chen & Yaping Zhang [13] used the SBM-DEA model to evaluate freight transport efficiency, and optimize freight structure . The findings offer new views on the development of carbon mitigation techniques in addition to important insights into freight structure optimization.

3. Methodology

3.1. Malmquist Productivity Index (MPI)

The variation in total factor productivity of DMUs in two periods are expressed by the MPI values, being defined as the product of technical efficiency change (catch-up index) and technological change (frontier-shift index). Technical efficiency change is correlated with the power of the DMUs to get any efficiency improvements or deteriorations, while technological change indicates any progress in technology development and innovation of DMUs between periods 1 to 2. (by Chia-Nan Wang, 2020)

The authors named that the DMU_i at the period 1 is (a_i^1, b_i^1) and at the period 2 is (a_i^2, b_i^2). The efficiency score of the $DMU_i(a_i^1, b_i^1)^{t_1}$ is measured by the technological frontier t_2 : $d^{t_2}((a_i, b_i)^{t_1})$ $(t_1 = 1, 2$ and $t_2 = 1, 2)$.

To compute for the catch-up index (C), frontier-shift index (F), and Malmquist Index (MI), the following formulas can be applied:

$$C = \frac{d^2((a_i, b_i)^2)}{d^1((a_i, b_i)^1)}$$

$$F = \left[\frac{d^1((a_i, b_i)^1)}{d^2((a_i, b_i)^1)} \times \frac{d^1((a_i, b_i)^2)}{d^2((a_i, b_i)^2)}\right]^{\frac{1}{2}}$$

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$$MI = C\ x\ F = \frac{d^2((a_i,b_i)^2)}{d^1((a_i,b_i)^1)} \times \left[\frac{d^1((a_i,b_i)^1)}{d^2((a_i,b_i)^1)} \times \frac{d^1((a_i,b_i)^2)}{d^2((a_i,b_i)^2)}\right]^{\frac{1}{2}}$$

$$MI = \left[\frac{d^1((a_i,b_i)^2)}{d^1((a_i,b_i)^1)} \times \frac{d^2((a_i,b_i)^2)}{d^2((a_i,b_i)^1)}\right]^{\frac{1}{2}}$$

It can be seen from the above equations that the DMU's total factor productivity (TFP) shows the increases or decreases of the DMUs in technical efficiency and technological innovation efficiency, respectively. Technical efficiency change, technological change, and the total factor productivity of DMU_i from period 1 to 2 achieved progress, stable, or regress when the value of C, F, and MI are > 1, = 1, or < 1, respectively. (by Chia-Nan Wang, 2020)

3.2. Person Correlation Coefficient

The Pearson correlation is generally used in many previous studies. It has a value between -1 and +1, describing the linear dependence of two variables or sets of data, where +1 is a total positive linear correlation, 0 is no linear correlation, and -1 is a total negative linear correlation.

The correlation coefficient equation of Pearson's (r) of two variables (x) and (y) is computed below:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}}$$

Where: n is the size of the sample; x_i , y_i represents the individual sample points indicated with i; Moreover, $\bar{x} = \frac{1}{n}\sum_1^n x_i$ is the mean of the sample, which is similar for $\bar{y}$.

Because the homogeneity and isotonicity are two critical DEA data assumptions, these do the correlation test an imperative step before using DEA. This is a certainty that there is an isotonic condition between input and output variables. The input and output data must have a positive correlation (i.e. the closer the value to +1, the better positive linear correlation). (by Chia-Nan Wang, 2020)

4. Results and Discussion

4.1. Select of Decision - Marking Unit (DMUs)

After considering about 33 firms on the stock market, the authors have selected 11 major companies to conduct research. In this paper, Table 1 of the data of 11 of Taiwan's top shipping line companies.

The DEA is a complex method in which the input and output variables have a significant on the outcome. Selecting inputs and outputs is an essential duty in applying DEA to estimate the performance of eleven shipping line companies. In this study, the authors considered three input and two output factors, as below.

Table 1. List of shipping line company in Taiwan

DMU	Shipping line Company
DMU1	Evergreen
DMU2	Yang Ming
DMU3	Tze Shin
DMU4	First Steamship
DMU5	Sincere Navigation
DMU6	U-Ming
DMU7	Taiwan Line
DMU8	Taiwan Navigation
DMU9	Franbo Lines
DMU10	Chien Shing
DMU11	China Container

[Yahoo.finance.vn]

4.2. Choosing Input and Output Factors

This research aim to estimate the performance the business of DMUs strategies. Selecting inputs and outputs is not only important but also must be consistent with the DEA resolution program. In this study, the author considered three inputs and two outputs, which declared as follows Table 2.

Table 2. Input and Output factors and definitions

Input	**Description**
Total Asset (TA)	the total amount of assets of value a business owns (as cash, equipment, tools, property, etc)
Liabilities (LI)	Liabilities are debts that a company has to pay, and when the payment is due Stockholders' equity refers to
Stockholders ' Equity (SE)	the assets remaining in a business once all liabilities have been settled
	Description
Output	Gross profit is the measure of a
Gross profit (GP)	company's profits directly stemming from its sales after accounting for the Cost of Goods Sold or COGS
Revenue	Revenue represents the total income generated by a company from its primary operations, typically from sales of goods or services

4.3. Discussion

4.3.1. Catch-Up Index (Technical Efficiency)

The catchup-up index is a measure of the technical effective modification of the shipping line, as shown in Table 3 and Fig 1. In 2020-2023, all shipping lines will grow efficiently.

Table 3. Result of catch up index

Catch-up	2020=>2021	2021=>2022	2022=>2023	Average
Evergreen	0.77702511	0.937608855	1.1519527	0.9555289
Yang Ming	1.04083376	1.080453153	0.8842733	1.0018534
Tze Shin	1.68868638	1.103161879	1.4848501	1.4255661
First Steamship	0.320518	1.213584104	4.56636609	2.0334894
Sincere Navigation	0.55182653	0.987568884	1.3128279	0.9507411
U-Ming	1.18461794	0.983918566	1.98379949	1.384112
Taiwan Line	0.926792	1.141115209	1.25317957	1.1070289
Taiwan Navigation	0.71654288	0.960021753	2.91646563	1.5310101
Franbo Lines	0.93474495	0.79674016	4.54525411	2.0922464
Chien Shing	0.54677161	0.959320575	1.94291628	1.1496695
China Container	0.74023163	1.026132893	1.63633917	1.1342346
Average	0.85714462	1.01723873	2.15256585	1.3423164
Max	1.68868638	1.213584104	4.56636609	2.0922464
Min	0.320518	0.79674016	0.8842733	0.9507411
SD	0.36887532	0.1135492	1.30550944	0.4048481

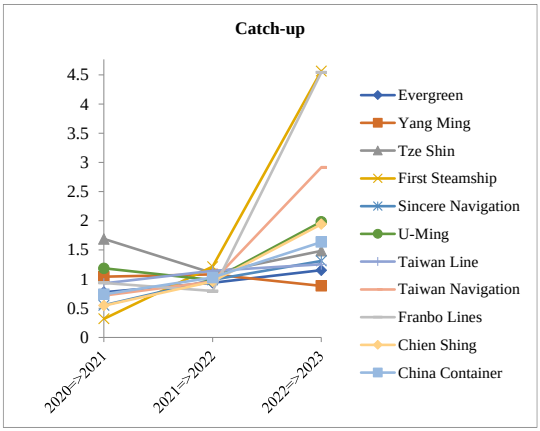

Figure 1. Each DMU's technical efficiency changes

Among the 11 shipping lines, 9 achieved efficiency between 2020 and 2023, with an average catch-up index of better than 1. The DMU with the highest technical efficiency was First Steamship, with a value of 2.0334894. Conversely, Sincere Navigation scored 0.9507411, the lowest average. The technically efficient producer for each of the 11 shipping lines in the table received an average score of 1.3423164. In 2020-2021, the bulk of the 11 shipping companies progressively decline. The trends for the 2021-2022 and 2022-2023 periods show an increase, with scores of 1.0172387 and 2.1525658, respectively. The shipping line companies' technical efficiency showed a significant increase in 2022-23-23. The results indicate that all shipping lines had the best efficiency with scores > 1 from 2020-2021 to 2021-2022. Yang Ming, on the other hand, had the lowest efficiency during this time, with a score of 0.8842733.

4.3.2 Frontier - Shift Index (Technological Change)

The frontier-shift index is used to calculate the shipping line enterprises' efficiency frontiers over time. Table 4 shows that shipping line companies' technological efficiency increased in 2020-2021 and decreased in 2022-2023.

Table 4. Result of frontier -shift index

Frontier	2020=>2021	2021=>2022	2022=>2023	Average
Evergreen	2.7785751	0.9171479	0.3198329	1.3385187
Yang Ming	2.4029517	0.9318411	0.3556537	1.2301488
Tze Shin	1.4735546	0.9973582	0.4816376	0.9841835
First Steamship	4.0277252	0.9097351	0.1861292	1.7078631
Sincere Navigation	1.8855328	0.9869902	0.5927205	1.1550811
U-Ming	1.7147738	0.9400527	0.4029441	1.0192569
Taiwan Line	0.9778519	1.0586781	0.6753844	0.9039715
Taiwan Navigation	2.4748833	1.0158213	0.3959294	1.2955447
Franbo Lines	2.4064911	0.9825119	0.2687438	1.2192489
Chien Shing	2.1933685	0.9797133	0.4070437	1.1933752
China Container	1.5233854	0.9845076	0.5421528	1.0166819
Average	2.1690085	0.9731234	0.4207429	1.1876249
Max	4.0277252	1.0586781	0.6753844	1.7078631
Min	0.9778519	0.9097351	0.1861292	0.9039715
SD	0.8147212	0.0448695	0.1437199	0.2209934

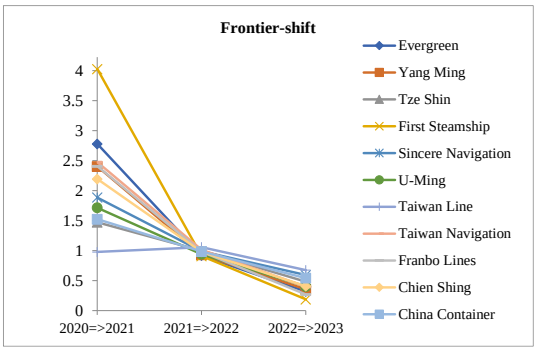

Figure 2. Each DMU's Technological changes

All of the research's shipping line companies have greater technological efficiency in 2020-2021 with sores >1. But after the years 2021-2022 and 2022-2023, every one of their frontiers-shift indicators dropped.

Figure 2 illustrates how the shipping line industry failed to achieve technological breakthroughs between 2022 and 2023; all shipping lines with a score of less than 1 failed to do so. According to this study, these businesses' advantages in terms of innovation and technology have not changed much and are still subject to numerous limitations. Fig. 2 shows the frontier-shift scores for the top shipping

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line for the 2020-2021 year. During this period, Taiwan line manufacturers had the lowest efficiency (0.9778519). Conversely, every shipping line exhibiting superior performance (>1).

All things considered, Taiwan's shipping lines show a typical pattern of rising in the first phase and dropping in the next two.

4.3.3. Malmquist Index (MPI)

This study estimates the efficiency performance of Taiwan's top 11 shipping lines using the DEA-Malmquist model.

Table 5. Result of Malmquist

Malmquist	2020=>2021	2021=>2022	2022=>2023	Average
Evergreen	2.1590226	0.859926	0.3684324	1.129127
Yang Ming	2.5010732	1.0068106	0.3144951	1.2741263
Tze Shin	2.4883716	1.1002476	0.7151596	1.4345929
First Steamship	1.2909584	1.10404	0.8499338	1.0816441
Sincere Navigation	1.040487	0.9747208	0.7781399	0.9311159
U-Ming	2.0313519	0.9249353	0.7993604	1.2518825
Taiwan Line	0.9062653	1.2080737	0.846378	0.9869057
Taiwan Navigation	1.77336	0.9752105	1.1547145	1.301095
Franbo Lines	2.2494554	0.7828067	1.2215087	1.4179236
Chien Shing	1.1992716	0.9398591	0.7908517	0.9766608
China Container	1.1276581	1.0102356	0.8871458	1.0083465
Average	1.7061159	0.9897151	0.7932836	1.1630382
Max	2.5010732	1.2080737	1.2215087	1.4345929
Min	0.9062653	0.7828067	0.3144951	0.9311159
SD	0.6083754	0.1185137	0.2729395	0.1814535

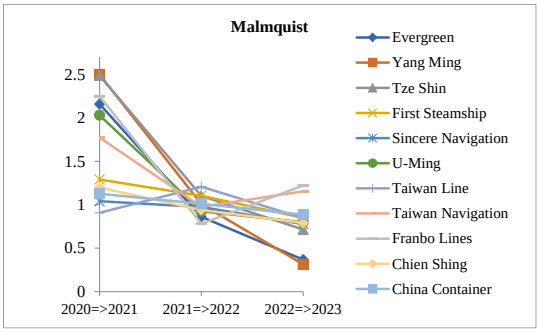

Figure 3. Total factor productivity changes

Table 5 and Fig. 3 provide specifics on the Malmquist productivity index of the leading shipping line for the years 2020-2023. All things considered, it is clear that the MPI of the majority of the leading shipping lines tended to rise between 2020 and 2021 and decline between 2021 and 2022.

In the top shipping line, the average growth rate of total productivity is 1.16303. Tze Shin has, on average, performed the best during the time in terms of technical and technological efficiency. Out of the eleven shipping lines, Sincere Navigation is the lowest.

Ten shipping line companies made greater than one progress in overall factor productivity in 2020-2021. There was only one MPI score below 1 for Tawan Line. During this time frame, the average MPI for all shipping line businesses is 1.706.

5. Conclusion

Data envelopment analysis is used in the study to compare the effectiveness of 11 Taiwanese shipping businesses. This model employs assets, stockholders equity, and liabilities as inputs and revenue and gross profit as output variables based on the major financial indicators. According to the estimated results, the overall efficiency of the Evergreen, Yang Ming, Tze Shin, U-Ming, Taiwan Navigation, and Franbo lines is relatively high. The contribution of the article is to provide an evaluation and comparison of the operations of 11 firms. This study provides useful information management for competitive decision-making in networked company. To achieve economic progress, the evaluation might provide insightful data and boost productivity. This study provides an overview of the shipping line business to assist managers in carefully considering how to improve shipping services in order to improve shipping line performance, in addition to providing helpful information for future research.

Future research should consider other input and output variables, such as cost, investment, and equipment, in order to provide a higher degree of resolution for the performance ratings, given the limits of this paper. The indicated inefficiency's source or solution is not guaranteed by DEA. To identify the kinds of operational modifications that can result in efficiency gains, internal audits or peer reviews are required. Completing them in the next research would be a worthwhile endeavour

In conclusion, this paper's managerial implications help decision - makers understand how their company fits into the container shipping line sector and how to measure overall productivity and efficiency. Managers can use the study's findings to inform their investment decisions and improve the index's financial performance

REFERENCES

[1] Charnes, A., Cooper, W.W. and Rhodes, E. (1978) *Measuring the Efficiency of Decision Making Units*, European Journal of Operational Research, Vol.2, pp.429-444.

[2] Lin, W. C., Liu, C. F., & Chu, C. W. (2005). *Performance efficiency evaluation of the Taiwan's*

shipping industry: an application of data envelopment analysis. In Proceedings of the Eastern Asia Society for Transportation Studies Vol. 5, No. 1, pp.467-476. Citeseer.

[3] Liu, B. L., Liu, W. L., & Cheng, C. P. (2008). *The efficiency of container terminals in mainland China: An application of DEA approach*. In 2008 4th International Conference on Wireless Communications, Networking and Mobile Computing (pp. 1-10). IEEE.

[4] Chao, S. L., Yu, M. M., & Hsieh, W. F. (2018). *Evaluating the efficiency of major container shipping companies: A framework of dynamic network DEA with shared inputs*. Transportation Research Part A: Policy and Practice, Vol.117, pp.44-57.

[5] Nguyen, H. O., Nguyen, H. V., Chang, Y. T., Chin, A. T., & Tongzon, J. (2016). *Measuring port efficiency using bootstrapped DEA: the case of Vietnamese ports*. Maritime Policy & Management, Vol.43(5), pp.644-659.

[6] Chang, H. J., & Liao, L. C. (2012). *Using the data envelopment analysis (DEA) model to evaluate the operational efficiency.* African Journal of Business Management, Vol.6(37), 10143.

[7] Lee, P. F., Lam, W. S., & Lam, W. H. (2023). *Performance evaluation of the efficiency of logistics companies with data envelopment analysis model*. Mathematics, Vol.11(3), 718p.

[8] Nguyen, D. D., Park, G. K., & Choi, K. H. (2019). *The performance analysis of container terminals in Vietnam using DEA-Malmquist*. Journal of Navigation and Port Research, Vol.43(2), pp.101-109.

[9] Wang, C. N., Nguyen, N. A. T., Fu, H. P., Hsu, H. P., & Dang, T. T. (2021). *Efficiency assessment of seaport terminal operators using DEA Malmquist and epsilon-based measure models*. Axioms, Vol.10(2), 48p.

[10] Sueyoshi, T., Yuan, Y., & Goto, M. (2017). *A literature study for DEA applied to energy and environment*. Energy Economics, Vol.62, pp.104-124.

[11] Agüero-Tobar, M. A., González-Araya, M. C., & González-Ramírez, R. G. (2023). *Assessment of maritime operations efficiency and its economic impact based on data envelopment analysis: A case study of Chilean ports*. Research in transportation business & management, Vol.46, 100821p.

[12] Krmac, E., & Mansouri Kaleibar, M. (2023). *A comprehensive review of data envelopment analysis (DEA) methodology in port efficiency evaluation*. Maritime Economics & Logistics, Vol.25(4), pp.817-881.

[13] Chen, R., & Zhang, Y. (2024). *Freight transport structure evaluation and optimization toward sustainable development: New evidence from the SBM-DEA model with undesirable outputs. Environment*, Development and Sustainability, Vol.26(6), pp.14257-14280.

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