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COLLABORATION ENHANCES UTILIZATION OF PRODUCTION FACTORS IN CONTAINER SHIPPING INDUSTRY

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COLLABORATION ENHANCES UTILIZATION OF PRODUCTION FACTORS IN CONTAINER SHIPPING INDUSTRY

Rong-Her Chiu and Dong-Hua Wang

Key words: collaboration, ccv, csu, production factors, shipping alliance, superadditivity.

ABSTRACT

This study investigates both theoretically and empirically the economic impact of collaborative operation between container carriers. Using the property of superadditivity of the Leontief production function, this study aims to demonstrate that the utilization rate of production factors will improve when liner carriers collaboratively provide services through a strategic alliance. Two production factors, containership slot utilization (CSU) and container circulation velocity (CCV), are used to empirically prove the existence of the efficiency improvement effect after 2000 (since 2000, strategic alliances have become a formal collaborative mechanism and have been restructured continuously).

I. INTRODUCTION

The shipping business is essential for promoting economic activities between countries that span different geographic regions. Global trade relies on ships to transport cargo for facilitating economic exchange. As an important element of economic development, shipping has a long history that dates back to 1700 BC. However, since the advent of containerization in 1956, the container transport industry has rapidly grown (Song et al., 2005) and has profoundly changed the relationships among the players in the chain of cargo transport. According to Lun and Browne (2009), the operating environment of container shipping is driven by 4Cs: containerization, concentration, collaboration, and competition. Wang (2014) discovered that the amendment of the US Ocean Shipping Reform Act (OSRA), which came into force in 1999, has spurred maritime container freight rate competition. Because of fierce competition and low profit margins, some container carriers have formed collaborations with other container carriers; the nonprice setting strategic alliance has been the most common collaboration. Lun et al. (2010) pointed out that for container carriers, the major purposes of alliances are to accomplish the organizational objective of achieving operational gains, which can be presented in many dimensions including financial, economic, strategic, marketing, and operational objectives (Table 1).

Similar to globalization and deregulation, shipping alliances developed gradually. Upon recognizing the advantages of operational cooperation, carriers initially ventured into space chartering, joint services, and vessel-sharing arrangements that were typically confined to a single trade lane. Positive experiences in deployments and vessel-sharing cost savings before the 1990s led to more cooperation and ultimately to global strategic alliances. The container shipping market is currently dominated by alliances which essentially maximize the advantage of operational cooperation while maintaining an individual carrier's marketing objectives. Alliance partners work to ensure efficiency across the entire gamut of shared operational assets such as vessels, containers, maritime terminals, equipment, and inland facilities (Lun et al., 2009). Alliances generally improve the productivity and quality of available liner shipping services because of the rationalization of the activities of member companies and the economies of scale in the operation of vessels and utilization of port facilities. In addition, users of the shipping services provided by alliances obtain a fair share of the benefits resulting from the improvements in productivity and service quality (European Shipper Council 2004).

The formation of alliances and the integration of shipping lines have accelerated since the late 1990s. Due to operational environment's challenges such as large vessel size and intermodality, shipping companies must collectively devise strategies in response to large enterprises with huge vessels, and by collaborating with other lines, shipping companies can offer the most flexible services; this effort has boosted alliances among shipping firms (Lee and Song, 2015). As shown in Table 2, in response to another wave of integration of container carriers, shipping alliances have been more quickly and frequently forged and reorganized after 2000. Moreover, the industry shows a net shift and an exponential growth of the concentration of carriers through mergers and acquisitions (Sanchez and Mouftier, 2017). In ad-

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Table 1. Objectives of shipping alliances.

Objectives	Details
Financial	Profit maximization, capital investment sharing, and financial risk reduction.
Economic	Cost reduction, economies of scale, increase ship slot, and container utilization.
Strategic	Entry into new markets and expansion of geographical influence.
Marketing	Satisfying customer requirements, higher shipping frequency, and greater variety of routes and destinations.
Operational	Increase in the frequency of services, vessel planning, and better coordination of global operations.

Sources: Adapted and revised from Lun et al. (2010).

Table 2. Evolution of big liner shipping alliances (1996-2017).

1996			
Main partners	Global Alliance APL, Nedlloyd, MOL, OOCL, MISC	Grand Alliance Hapag-Lloyd, NYK, NOL, P&OCL	Hanjin/Tricon Cho yang, DSR/Senator, Hanjin
Capacity (TEU)	209,645	255,705	199,404
No. of vessels	65	72	72

2000			
Main partners	New World Alliance APL-NOL, MOL, HMM	Grand Alliance Hapag-Lloyd, P&O, Nedlloyd, OOCL, MISC	United Alliance Cho yang, DSR/Senator, Hanjin
Capacity (TEU)	325,487	350,197	277,000
No. of vessels	90	93	85

2006			
Main partners	New World Alliance APL, MOL, HMM	Grand Alliance Hapag-Lloyd, OOCL, MISC Berhad, NYK	CKYH Hanjin, Yang Ming, K Line, COSCO
Capacity (TEU)	712,082	966,570	1,046,991
No. of vessels	223	Approx. 350	354

2010			
Main partners	New World Alliance APL, MOL, HMM	Grand Alliance NYK, Hapag-Lloyd, OOCL	CKYH Hanjin, Yang Ming, K Line, COSCO
Capacity (TEU)	1,161,468	1,187,607	1,548,508
No. of vessels	282	288	400

2016				
Main partners	2M Maersk, MSC	G6 Hapag-Lloyd, HMM, MOL, NYK, OOCL, APL	Ocean 3 CMA CGM, UASC, China Shipping	CKYH COSCO, Hanjin, K Line, Yang Ming, Evergreen
Capacity (TEU)	5,662,864	3,454,271	3,034,821	3,334,904
No. of vessels	1,068	610	642	626

2018			
Main partners	2M (+HMM) Maersk, MSC, +HMM	Ocean Alliance CMA CGM, COSCO, Evergreen, OOCL	THE Alliance Hapag-Lloyd, K Line, NYK, MOL, Yang Ming
Capacity (TEU)	7,640,409	6,076,844	3,626,036
No. of vessels	1,340	1,140	548

Sources: 1. Panayides and Wiedmer (2011); 2. Varbanova (2017); 3. Alphaliner-Top 100 (January 13, 2016; January 02, 2018).

dition to organizational changes, all alliances have increased both in the number of operated vessels and in overall capacity.

An alliance is a type of economic collaboration of liner carriers. Zeckhauser (2017) indicated that "attempting collaboration provides option value" and "collaborative is superadditive" in production. In this study, we empirically assess the economic effects of alliances on the performance of the liner industry (which is presented as an increase in the utilization of production factors). The Leontief production function is adopted to evaluate the hypothesis that complementary resources from the operation of a shipping alliance can confer competitive advantages (Lorange and Roots, 1992). Two measures (containership slot utilization [CSU] and container circulation velocity [CCV]) that evaluate operating efficiency are used as benchmarks for assessing whether production efficiency has dramatically improved in the liner market after 2000 (since 2000, strategic alliances have become a formal collaborative mechanism and have been restructured continuously).

II. LITERATURE REVIEW

The literature review focuses on three main areas: collaboration of liner shipping, production efficiency of container shipping, and slot utilization of containership.

1. Collaboration of Container Shipping

The cooperative mechanism of liner shipping can be traced to 1875 when the first liner conference was conducted for the UK/Calcutta (India) trade route. A liner conference is a type of price-fixing agreement between carriers; in the conference, the following challenges were encountered: the US OSRA in 1998 and the EU appeal of the exemption of anti-trust rules in 2008. Since the mid-1990s, in ocean shipping, a new type of cooperative agreement has become popular, namely the strategic (global) alliance (Varbanova, 2017). The main feature of strategic alliances is the coordination of liner shipping services and cooperation, instead of price setting, which is the major objective of conferences. Scientific investigation of this feature has been conducted from various aspects such as liner shipping structure, types of alliances, liner alliance stability and success, and objectives for alliance formation in liner shipping (Panayides and Wiedmer, 2011).

Sjostrom (2010) reviewed primary models to explain competition and collaboration in liner shipping. Using game theoretic models, other researchers have conducted empirical examination of the behavior of liner companies within strategic alliances (Parkhe, 1993; Panayides and Song, 2001; Song et al., 2001). Shashikumar (1995) and Midoro and Pitto (2000) have summarized the features of modern alliances in liner shipping. Lun et al. (2009) pointed out that a liner shipping network is a form of collaboration in the liner shipping industry, where players such as intermodal service providers, container management service providers, and container terminal operators share resources and develop mutually beneficial strategies. The development of a liner shipping network can reduce costs in areas such as container handling and intermodal feeder services (Midoro and Pitto, 2000), can improve destination coverage (Bergantino and Veenstra, 2002), and can ensure lower operating costs and the realization of scale economies (Gilman, 1999; Heaver et al., 2001; Dyer et al., 2004).

Although strategic alliances have obvious advantages, some liner shipping companies have experienced instability and change in strategic direction. Hence, in recent years, companies have given great consideration to whether alliance or acquisition is the most effective strategy for achieving organizational objectives and growth (Alix et al., 1999). Midoro and Pitto (2000) pointed out that intra-alliance competition is the key force of alliance instability; to achieve alliance stability and efficiency, they suggested the following three measures: (1) reduction in number of partners; (2) differentiation in their roles and contributions; and (3) coordination of sales and marketing activities.

Container shipping companies have been engaged in cooperative enterprises since the beginning of containerization. From rate and capacity agreements in the conferences, to slot charter and joint service provisions, shipping lines have engaged in a wide range of joint ventures. However, the overall growth in the number of vessels after 2000 could not possibly explain the magnitude of new service offerings. That is, the net addition of vessels for most carriers is insufficient and could not account for the proliferation of services, particularly the number of weekly sailings (Slack et al., 2002). It can be concluded that membership in an alliance has facilitated the expansion of throughputs without commensurate increases in the numbers of slots and container fleets. According to the property of superadditivity, participating in a large coalition yields more value than remaining as separate companies (Zeckhauser, 2017). Therefore, it should be investigated whether collaboration among container carriers can enhance the production factors of container shipping.

2. Production Efficiency of Container Shipping

Panayides et al. (2011) described that a common driving factor across the key sectors of the shipping industry is the optimization of costs and the improvement of efficiency; in addition, the growth of the global economy is directly related to efficient transportation. Hence, analysis of economic phenomena in transport would facilitate efficiency improvements and promote economic growth; such analysis is fundamental. Production factors are inputs for producing goods and services; labor, land, and capital are the three most important production factors (Mankiw, 2015), and probably management is the fourth important production factor (Goss, 1984). Productivity is the single most important measure of the success or efficiency of a manufacturing organization. Stevenson (2007) pointed out that productivity is distinct from efficiency. Efficiency is a narrower concept that pertains to obtaining maximum outcomes from a fixed set of resources; productivity is a broader concept that pertains to the effective use of overall resources.

Data envelopment analysis (DEA) has been widely used to measure the efficiency of the transport sector; it has especially been used in the evaluation of airports, ports, railways, and urban transport companies. DEA is a nonparametric linear programming method used for determining the efficiency of a set of companies, as compared with the best practice frontier (Markovits-Somogyi, 2011). As initially proposed by Charnes et al. (1978), DEA has been revised through a series of theoretical extensions (Cooper et al., 2007). Bang et al. (2012) measured the relative efficiency of liner shipping companies in terms of operational and financial performance; in a two-stage DEA, relative efficiency is measured using a linear programming technique in the first stage, and the effects of relevant factors on relative efficiency are examined using the Tobit regression in the second stage. The results show that most operational factors make a positive contribution to financial performance; however, none of these factors are significant for operational performance.

Chao (2017) proposed a multistage DEA model to evaluate the efficiency of global liner shipping companies. Using this multistage DEA model, shipping companies can effectively identify bottlenecks in their production processes and further improve them by adjusting the values of the corresponding input and output variables. Although the DEA model is widely used to evaluate efficiency performance, Button (2005) pointed out two weaknesses in the results of DEA; first, it does not identify the most efficient player, and second, shipping service suppliers may be outside the minimum cost envelope.

In addition to the DEA model, some researchers explore different shipping efficiency issues and utilize various analytical methods. Yip, Lun, and Lau (2012) discussed the economies of scale problem for liner shipping companies; they introduced the S-curve to determine the association between capacity and firm performance. By examining empirical data for the period during 1997-2008, they concluded that the S-curve is applicable to liner shipping companies. In 1998, Lim (1998) also determined the association for liner shipping based on the theoretical justification that very large container ships are built because they will produce economies of scale. Based on an analysis of data on the shipping market, he concluded that although major operators significantly reduced slot costs by using newer and bigger ships, container carriers had not reaped the benefits of those savings because most freight rates had dropped more than the cost reductions. The research results suggest that "carriers must find some way to return to profitability, and cooperation between the carriers is highly desirable."

3. Slot Utilization of Containership

Some researchers have studied slot utilization from the perspective of individual containerships or companies. Using the concept of revenue management (RM), Ting and Tzeng (2004) proposed a conceptual model of liner shipping revenue management (LSRM) to provide carriers with reference solutions to build their RM systems. Then, an optimal slot allocation model was formulated, with the objective of maximizing the total freight contribution in the liner company. Optimal slot allocation can be a guideline for distributing space to every calling port to achieve the highest expected contribution; however, the persons in charge should monitor space usage and adjust allocation to avoid unused space. Lu et al. (2010) proposed an integer programming model for slot allocation planning by carriers for an alliance service with ship fleet sharing. The objective function is to maximize the sum of estimated profits, including the freight from various types of containers, the revenues from slots for sale, the costs of slot purchase, and the share of ship operating costs from the contributed ratio in a round trip voyage. To study the long-lasting under-utilization of fleet capacity in the container shipping industry, Wu (2012) discovered that "capacity utilization (CU) ratios depend explicitly on the existing economic conditions and some industry-related exogenous variables. These variations of CU ratios have further been interpreted in conjunction with the impacts of service route framework of a shipping line, demand condition and the shipping alliance behavior on the efficiency of fleet operation." Among those influencing factors, market demand has played a dominant role; the shipping alliance has also greatly improved the utilization of fleet capacity.

From the aforementioned review, most previous studies have focused on investigating the types of alliances and the benefits of alliances formed by individual carriers, such as lower operating costs or improvement of destination coverage; however, a few studies, for example the study by Wu (2012), have investigated how alliances enhance the slot utilization of containerships. Wu (2012) examined alliances from the individual carrier's perspective instead of the industry-wide perspective. The present study examines the economic impact of collaborative operation between container carriers and provides empirical results that demonstrate that the payoff of forming an alliance is to improve the utilization rate of production factors used in liner shipping. We treat the liner industry as a whole with operations on a global scale. By assuming two perfect complementary inputs (i.e., a one-to-one correspondence between containership slot and container quantity) contributed from different carriers, two sets of relationships are explored to examine the liner industry's performance (which is presented as the usage rate of production factors) before and after 2000.

III. THEORETICAL MODEL

Alliances are generally believed to promote technical and economic progress by facilitating and promoting high utilization of containers and efficient use of vessel capacity. However, the extent to which such strategic alliances lead to improvement in performance and confer a competitive advantage remains unclear.

The shipment of containers requires a one-to-one proportion between container boxes and slots. If inputs must be combined in fixed proportions, such as the combination of containers and vessel slots in the liner industry, the function is a fixed coefficient production (or Leontief) function. With inputs denoted by X (i.e., container) and Y (i.e., slot), the attainable level of throughput is given by $Q = \min\{X, Y\}$. In this case, to produce a given output in a technically efficient manner, the system must have a particular, or fixed, combination of containers and slots. To illustrate the complementary factors and superadditivity of the Leontief production function, we make the following assumptions for container shipments.

Before an alliance is formed, Carrier A's production function is $\mathrm{Min}(X_1, Y_1)$, and Carrier B's production function is $\mathrm{Min}(X_2, Y_2)$, where X and Y are containers and slots, respectively. To achieve a better interchange of their equipment, the formation of a collective equipment pool is the central objective of the alliance between Carrier A and Carrier B. This process can be enhanced through efficient sharing of pooled equipment between carriers. When all containers and slots are combined, the resulting joint production function is $\mathrm{Min}(X_1 + X_2, Y_1 + Y_2)$. An efficient sharing of pooled equipment between the carriers can be presented as

$$\mathrm{Min}(X_1, Y_1) + \mathrm{Min}(X_2, Y_2) \leq \mathrm{Min}(X_1 + X_2, Y_1 + Y_2) \quad (1)$$

Eq. (1), also known as superadditivity of the Leontief production function, requires that the payoff to a coalition between two players (Carrier A and B) is at least as good and perhaps better than the sum of the payoffs Carrier A and B receive as separate players. A proof of the following equation is detailed below.

According to the definition of the Leontief production function, the following two equations hold true:

$$\mathrm{Min}(X_1, Y_1) \le X_1 \text{ and } \mathrm{Min}(X_2, Y_2) \le X_2 .$$

Adding these two equations together yields:

$$\mathrm{Min}(X_1, Y_1) + \mathrm{Min}(X_2, Y_2) \le X_1 + X_2 \quad (2)$$

Similarly, we can also get:

$$\mathrm{Min}(X_1, Y_1) + \mathrm{Min}(X_2, Y_2) \le Y_1 + Y_2 \quad (3)$$

According to Eqs. (2) and (3), Eq. (1) must hold true, i.e.,

$$\mathrm{Min}(X_1, Y_1) + \mathrm{Min}(X_2, Y_2) \le \mathrm{Min}(X_1 + X_2, Y_1 + Y_2) .$$

The aforementioned discussion shows that collaboration between container carriers enhances their outputs with existing capacity commitment (Slack et al., 2002). The strategic alliance approach fits the needs of each party, with each party having complementary factors to contribute and gaining specific advantages from joint operation. Thus, the trend among large carriers to rationalize operations through the formation of global alliances and partnerships may effectively improve container throughputs with the existing quantity of containers and vessel's slots (or reduce the overall need for containers to service existing ship slots). The aforementioned theoretical analysis leads to two insights about the benefits of collaboration between container carriers:

1. Through the formation of strategic alliances, carriers use vessel capacity more efficiently; that is, it effectively improves CSU, which determines the number of times a containership slot is utilized to transport containers globally in a year.
2. The formation of strategic alliances can enable greater utilization of containers by carriers; that is, joint service improves CCV, which is determined by the ratio of global container port traffic to the global container fleet in a year.

IV. EMPIRICAL STUDY

After 2000, liner companies have implemented cost-cutting strategies and efficiency improvement measures (Panayides and Cullinane, 2002). As shown in Table 2, alliances became popular for the top 20 container carriers. The extent to which such strategies improve performance and confer a competitive advantage remains unclear. To provide empirical evidence (Panayides and Cullinane, 2002) on the operating efficiency of the liner industry, this section provides an empirical examination of the impact of carriers' cooperative actions.

The Containerization International Yearbook (1990-2010) and Review of Maritime Transport (2011-2017) were used as the main data sources. To examine the effect of collaboration on production efficiency, data for the period from 1990 to 2016 were collected from various sources, including data on global container port traffic, world container fleet, and global containership slots.

Global container port traffic (or throughput) statistics indicated new records of overall container traffic each year. As seen in Table 3, the total throughput increased rapidly. During the 27-year period, it increased more than 8.17 times from approximately 85.5 million TEUs in 1990 to 699.7 million TEUs in 2016. The number and size of vessels steadily increased in the last three decades, and the vessel total carrying capacity also steadily increased. The volume of global total vessel slots increased from only 3.16 million TEUs in 1990 to more than 19.9 million TEUs in 2016. The global maritime container fleet size was only 6.01 million TEUs in 1990 and surpassed 38.2 million TEUs in 2016.

According to the data listed in Table 3, the following two indices can be derived:

(1) CSU, which determines the number of times a container slot is utilized to transport containers globally during a year. CSU increased from 27 containers per slot in 1990 to 35 per slot in 2016. A dramatic change in CSU occurred after 2000 since forming shipping alliances became more popular. Thus, the index increased from 32.4 in 1999 to 35.0 in 2016.

(2) CCV is the average number of times a container is circulated around the world in one year. It is determined by the ratio of global container port traffic to the global container fleet. The CCV index increased rapidly from 15.98 in 1999 to 18.31 in 2016 after 2000.

The aforementioned indices changed substantially since 2000, implying that the operating efficiency of container shipment after 2000 may outperform efficiency before 1999. In econometrics, the Chow test (Maddala, 1977) is the most commonly used in time-series analysis to examine the presence of a structural break. In this study, the Chow test is employed to determine whether the independent variables have different impacts on different subgroups of the population.

1. Structural Changes after 2000

This study examines the changes in services made by the container shipping industry in response to its restructuring after 2000. Within the aforementioned different periods, CCV is examined using the data in Table 3. Analyzing the data separately in the first 10 years (from 1990 to 1999) and the subsequent 17 years (from 2000 to 2016) yielded the following results.

Table 3. Quantity of global container port traffic, global containership slot, and global maritime container fleet (1990-2016).

Year	World container port traffic ('000 TEU)	Global containership slot ('000 TEU)	Global maritime container Fleet ('000 TEU)	Containership slot utilization (CSU index)	Container circulation velocity (CCV index)
1990	85,597	3,168	6,018	27.02	14.22
1991	93,646	3,373	6,522	27.76	14.36
1992	102,906	3,611	7,215	28.50	14.26
1993	113,212	3,743	7,372	30.25	14.76
1994	128,320	4,102	8,087	31.28	15.87
1995	137,239	4,408	8,894	31.13	15.43
1996	150,753	4,834	9,656	31.19	15.61
1997	165,234	5,266	10,611	31.38	15.57
1998	181,982	5,878	11,352	30.96	16.03
1999	195,261	6,021	12,219	32.43	15.98
2000	225,294	6,537	13,448	34.46	16.75
2001	236,698	7,271	14,374	32.55	16.47
2002	266,337	7,751	16,560	34.36	16.08
2003	303,108	8,320	18,085	36.43	16.76
2004	356,678	8,959	19,965	39.81	17.87
2005	387,693	9,763	21,415	39.71	18.11
2006	434,302	11,154	23,335	38.94	18.61
2007	487,132	12,533	26,295	38.87	18.53
2008	515,763	14,145	27,854	36.46	18.52
2009	469,003	14,908	27,165	31.46	17.26
2010	540,693	16,091	28,995	33.61	18.65
2011	580,022	16,254	30,630	35.68	18.94
2012	616,675	17,909	31,563	34.43	19.54
2013	651,201	16,058	34,685	40.55	18.77
2014	674,981	18,253	36,576	36.98	18.45
2015	686,690	19,735	37,643	34.80	18.24
2016	699,704	19,984	38,232	35.01	18.31

Sources: Compiled by authors based on (1) Containerisation International Yearbook, 1990-2012; (2) UNCTAD, Review of Maritime Transport, 2013-2016; (3) Drewry, Container Census report, various issues.

From 1990 to 1999:

$$CCV = 14.003 + 0.219 \times (T - 1989) \quad (4)$$
$$(61.886)(6.015)$$
$$R^2 = 0.819, \text{Residual sum of square} = 4.846, n = 10$$

From 2000 to 2016:

$$CCV = 15.332 + 0.14 \times (T - 1989) \quad (5)$$
$$(22.692)(4.066)$$
$$R^2 = 0.524, \text{Residual sum of square} = 15.253, n = 17$$

For the Entire Period from 1990 to 2016

$$CCV = 14.297 + 0.19 \times (T - 1989) \quad (6)$$
$$(58.517)(12.480)$$

where

$$R^2 = 0.862, \text{Residual sum of square} = 68.857, n = 27.$$

The numbers in parentheses are t-statistics. To confirm that a structural change occurred after 2000, Maddala (1977) adopted the Chow test to estimate the regression equation with and without restrictions using the F-test:

$$F = \frac{(RRSS - URSS)/(k+1)}{URSS/(n_1 + n_2 - 2k - 2)}$$

where F is a distribution with degrees of freedom (k + 1) and ($n_1 + n_2 - 2k - 2$). The restricted residual sum of squares (*RRSS*) is obtained from the single regression of all data in the entire study period, and the unrestricted residual sum of squares (*URSS*) is obtained from separate regressions of different study periods.

When testing whether market structure was stable throughout the study period (1990-2016), the following results were obtained: *URSS* = (4.846 + 15.253 = 20.117), *RRSS* = 68.857, $k + 1 = 2$, and ($n_1 + n_2 - 2k - 2$) = 23. F = 27.862, which was significant at the 5 percent probability level. The 5 percent point in the F tables for degrees of freedom 2 and 23 was 3.42. Hence, the hypothesis of a stable relationship for the entire study period was rejected.

2. The Trend in the Two Indices

A dummy variable is a numerical variable used in regression analysis to represent subgroups of the sample in statistical analysis. A dummy variable (D) is often used to distinguish different treatment groups (Judge et al., 2000). To assess the impact of collaborative actions between carriers, time-series analyses were used to examine the trends in the two indices and to determine whether abrupt changes occurred in the level of intercept at the expected time points (2000) by using yearly data for the period between 1990 and 2016. By applying ordinary least squares (OLS), we obtained the following two results:

$$\begin{aligned} CSU &= 29.59 + 0.104(T - 1989) + 4.854 \times D \\ &\quad (33.860)(1.235) \qquad\qquad (3.646) \end{aligned} \tag{7}$$

where $R^2 = 0.685$, and the values in the parentheses are t-statistics. Yearly data are available for 27 observations (from 1990 to 2016) on the ratio of CSU to the time variable (T – 1989). The dummy variable (D) is set to 1 for observations from 2000 to 2016 (excluding 2009), which denotes a change in the intercept of the regression, and D is set to 0 for observations from 1990 to 1999 (including 2009). Considering the abnormal impact of the global financial crisis on the world economy, the data of 2009 are removed in the previous time series.

$$\begin{aligned} CCV &= 14.363 + 0.151(T - 1989) + 0.807 \times D \\ &\quad (63.313)(6.946) \qquad\qquad (2.337) \end{aligned} \tag{8}$$

where $R^2 = 0.887$, and the values in the parentheses are t-statistics. Yearly data are available for 27 observations (from 1990 to 2016) on the ratio of CCV to the time variable (T – 1989). The dummy variable (D) is set to 1 for observations from 2000 to 2016 (excluding 2009), which denotes a change in the intercept of the regression, and D is set to 0 for observations from 1990 to 1999 (including 2009).

In this paper, conventional dummy variables account for the structural change in economic relations by introducing an abrupt change in the intercept term at the time of the structural change. In the aforementioned two linear regression functions, the coefficient of D is interpreted as an estimation of the amount of upward shift in operating efficiency. The empirical results show the occurrence of a structural change in 2000, and liner industry production efficiency increases substantially following the formation of strategic alliances by container carriers.

3. Other Factors Influencing CSU and CCV

The improvement of production efficiency cannot be the sole reason for the collaborative action between carriers. Many factors may influence the improvement of CSU and CCV. Stopford (2009) included 10 major influencing factors in a shipping market model. The five demand side factors were the world economy development, seaborne commodity trades, average haul, random shocks, and transport costs; the supply side elements included the global fleet, fleet productivity, shipbuilding production, scrapping and losses, and freight revenue. Among these factors, the world economy development, seaborne commodity trades, and fleet productivity are directly related to the current study to some extent. Panayides et al. (2011) explored the relative efficiency of liner companies and mentioned that “the growth of the world economy is directly related to efficient transportation.” Based on previous investigations, increases in economic development and seaborne trade (which are presented as increases in global container port traffic) influence shipping operation. To achieve the goal of profitability, carriers also make efforts to improve fleet productivity.

To determine the extent of influence of global economic development and global seaborne trade on the improvement of shipping production efficiency (which are presented as the increase in CSU and CCV), a regression analysis is conducted using the data listed in Table 4. The results in Table 5 show that the world economic growth rate (WEGR) positively influences CSU and CCV over 1990-2016; nevertheless, the growth rate of container port traffic (CPTGR) only exerts a negative effect on CCV and statistically has no influence on CSU.

V. CONCLUSION AND DISCUSSION

1. Conclusion and Discussion

This study explores both theoretically and empirically the economic effects of the formation of strategic alliances between container carriers before and after 2000. Using the property of superadditivity of the Leontief production function, this study demonstrate that production efficiency improves when liner carriers collaboratively provide services through the formation of a strategic alliance. Two production factors, CSU and CCV, provide empirical proof of the existence of the production improvement effect after 2000. The results show that liner shipping strategic alliances, belonging to the discipline of new institutional economics (Button, 2005), can help the shipping market structure to improve economic efficiency; CSU and CCV after 2000 are higher than those before 1999. Wu (2012) discovered that the shipping alliance can improve the utilization of the fleet capacity of an individual carrier. This result also conforms to those of Zeckhauser (2017), in that collaboration will yield more value than remaining as separate companies.

Table 4. Growth rate of container port traffic and world GDP, CSU, and CCV (1990-2016).

Year	Container port traffic growth rate (CPTGR)(%)	World economic growth rate (WEGR)(%)	Containership slot utilization (CSU index)	Container circulation velocity (CCV index)
1990	7.24	3.00	27.02	14.22
1991	9.40	1.43	27.76	14.36
1992	9.89	1.79	28.50	14.26
1993	10.01	1.63	30.25	14.76
1994	13.34	3.01	31.28	15.87
1995	6.95	3.05	31.13	15.43
1996	9.85	3.38	31.19	15.61
1997	9.61	3.71	31.38	15.57
1998	10.14	2.52	30.96	16.03
1999	7.30	3.26	32.43	15.98
2000	15.38	4.37	34.46	16.75
2001	5.07	1.92	32.55	16.47
2002	12.52	2.15	34.36	16.08
2003	13.81	2.91	36.43	16.76
2004	17.67	4.46	39.81	17.87
2005	8.70	3.84	39.71	18.11
2006	12.02	4.32	38.94	18.61
2007	12.16	4.26	38.87	18.53
2008	5.88	1.82	36.46	18.52
2009	-9.07	-1.73	31.46	17.26
2010	15.29	4.32	33.61	18.65
2011	7.27	3.17	35.68	18.94
2012	6.32	2.44	34.43	19.54
2013	5.60	2.63	40.55	18.77
2014	3.65	2.85	36.98	18.45
2015	1.73	2.82	34.80	18.24
2016	1.90	2.49	35.01	18.31

Sources: Compiled by authors based on (1) Containerisation International Yearbook, 1989-2012; (2) UNCTAD, Review of Maritime Transport, 2013-2016; (3) Drewry, Container Census report, various issues; (4) GDP growth rate derived from World Bank: https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD.

Table 5. Results of regression analysis.

Independent variables	Dependent variables	R^2	β coefficient	Significance	Results
Constant	CCV	0.270	16.093	0.000*	Accept
CPTGR	CCV	0.270	-0.208	0.014*	Accept
WEGR	CCV	0.270	0.941	0.009*	Accept
Constant	CSU	0.239	30.416	0.000*	Accept
CPTGR	CSU	0.239	-0.262	0.168	Reject
WEGR	CSU	0.239	2.044	0.014*	Accept

Note: CPTGR = Container port traffic growth rate; WEGR = World economic growth rate; * $p < 0.05$.

In response to the argument of Stopford (2009) and Panayides et al. (2011) that efficiency improvement in shipping is possibly influenced by the growth of the world economy and other factors, this research conducts a relational analysis between the indices of CSU and CCV as well as investigates the growth rates of the world economy and container port traffic. The regression results (in Table 4) show that WEGR promotes the increase in CSU and CCV during 1990-2016. This may be attributed to the influence of the macroeconomic environment rather than the efforts of carriers for forming alliances to improve production efficiency. The results also show that growing container traffic in ports has negative effects on CCV and CSU. Although the causes warrant further study, one possible reason is port congestion from the "unexpected surges in cargo volumes" and "land side transport congestion blocking the discharge of more cargo as storage capacity is exhausted or overstretched" (World Shipping Council, 2015).

This research provides the following implications for related institutions. For shipping practitioners, the results directly suggest that liner carriers should practice joint alliance operations to acquire the benefits of improving the utilization of production factors. They can also obtain the advantages of low financial burdens for maintaining many container fleets on trade routes, sharing risks with partners, and expanding market coverage through forging strategic alliance agreements with other carriers. For policy makers, minimal control on shipping cooperative mechanisms will enhance the utilization of production factors; therefore, relevant governmental agencies are advised to adopt policies or rulings on shipping alliances that confer more freedom if shipping alliance operations do not undermine competition between carriers. For academia, this study provides an extensive review of the literature on shipping alliances. Furthermore, this study empirically demonstrates the existence of the superadditive effect on container carriers' collaboration by using long-term data to study shipping economics, which have received less attention (as noted by Button (2005)).

2. Further Study

Following this research, some potential issues should be resolved. First, how will the competition of liner carriers be affected? As shown in Table 2, the newly formed big three shipping alliances control over 80.2% of global total containerships' capacity. Although regulations have been implemented to monitor the operation of alliances, the recent consolidation trend has narrowed down shipping alliances; once there were many, and now, there are only three alliances. Will fewer shipping alliances result in a suffocating competitive environment, reducing options and weakening the negotiation power for shippers and freight forwarders?

Second, many factors definitely influence the operational efficiency of maritime transport. This study examines collaboration. Due to limited published data, only two factors (CSU and CCV) are used to test the existence of the improvement of production efficiency in this study. Additional studies may consider some other factors to increase the operational efficiency of container services, such as the use of a sophisticated IT/computer system, the rationalization of the container shipping industry for ensuring operation synergy, or the continued advances in logistics development noted by Notteboom and Rodrigue (2008). Finally, research should be conducted from the shippers' perspective. Most researchers have investigated shipping alliances from the perspective of carriers. The shipping community and forwarders have the concern that the new mega alliances will inevitably create disruption to global supply chains (Jaguar Freight, 2018). The obvious problem is that limited competition results in a lack of options, and that customer opinions are not considered in the discussion. When customers' views are not included in analyses, this may lead to the deterioration of value and customer service.

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