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發表論文題目: The Elasticity of Substitution between Owned and Leased Containers

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計畫名稱:國科會專題計畫–國籍貨櫃航商利潤函數之解析與實証

摘要

The International Forum on Shipping, Ports and Airports (IFSPA, 2013)係由香港理工學院，物流與航運系(The Hong-Kong Polytechnic University, Department of Logistics and Maritime Studies)所發起之國際會議，宗旨在擴展有關海運、港埠與物流領域的學術研究，以及促進相關實務應用之發展。本研討會期間已吸引多國的學者、政府機關、業界管理人員的參與，並已促進上述各相關研究領域之學術研究，以及相關實務管理應用之發展。

此次會議於 102 年 6 月 2 日至 102 年 6 月 5 日於香港理工大學國際會議中心舉行。於研討會中計涵蓋有關:港埠、航運、空運、物流以及供應鏈管理等領域之相關研究課題之探討，同時會議亦提供各國從事上述相關領域理論與實務之學者與機構一個交流的機會。而此次會議主題為: 貿易、供應鏈與運輸中當代物流與海運課題 (Trade, Supply Chains Activities and Transport: Contemporary Logistics and Maritime Issues)。會議期間除由多位國際級學者發表有關產業發展與學術研究發展之專題報告外，另亦涵蓋近百篇來自全球十餘國家學者有關：海運、運輸管理、供應鏈與物流管理等方面之學術與實務研究。

本研討會中本人親自發表一篇學術論文: The Elasticity of Substitution between Owned and Leased Containers。本論文旨在釐清租用櫃(leased container)與自有櫃間(owned container)是否為完全替代關係(Perfect substitution)。而透過此一核心問題之釐清，期將可作為貨櫃航商與貨櫃租賃商其貨櫃管理決策之依據。另外，在 Q＆A 過程中，本人與香港、韓國與日本等國多名學者，充分交換此一論文之研究心得，並對本人論文中的一些觀點，提出幾個見解相當不錯之建議，因此對未來本論文之修正頗有助益。同時，透過本研討會之參與，其不僅增加個人在對有關自有貨櫃與租賃貨櫃使用之理論思考，以及對航商與貨櫃租賃商在貨櫃存量決策之思考上，有更深層之體會。

目次

壹、前言

The International Forum on Shipping, Ports and Airports (IFSPA) 2013 係由香港理工學院，物流與航運系(The Hong-Kong Polytechnic University, Department of Logistics and Maritime Studies)所發起之國際會議，宗旨在擴展有關海運、港埠與物流領域的學術研究，以及促進相關實務應用之發展。本研討會期間已吸引多國的學者、政府機關、業界管理人員的參與，並已促進上述各相關研究領域之學術研究，以及相關實務管理應用之發展。

此次會議於 102 年 6 月 2 日至 102 年 6 月 5 日於香港理工大學國際會議中心舉行。於研討會中計涵蓋有關:港埠、航運、空運、物流以及供應鏈管理等領域之相關研究課題之探討，同時會議亦提供各國從事上述相關領域理論與實務之學者與機構一個交流的機會。而此次會議主題為: 貿易、供應鏈與運輸中當代物流與海運課題 (Trade, Supply Chains Activities and Transport: Contemporary Logistics and Maritime Issues)。會議期間除由多位國際級學者發表有關產業發展與學術研究發展之專題報告外，另亦涵蓋近百篇來自全球十餘國家學者有關：海運、運輸管理、供應鏈與物流管理等方面之學術與實務研究。

本次會議中，本人發表一篇探索貨櫃航商之貨櫃選擇行為論文。該文旨在以經濟學生產理論中之要素替代理論為基礎，來辯證航商自有櫃與貨櫃租賃商出租櫃間是否具完全替代之特性。若此，則依據經濟理論之意涵，則貨櫃租賃市場將出現兩種貨櫃價格競逐而至最後只出現一種貨櫃之結局，亦即是理論上所稱之角解(corner solution)結果。反之，則將出現具非完全替代關係之兩種貨櫃組合型態，進而更可衍生出探討自有櫃與租賃櫃組合之決定因素為何之實務課題。

貳、會議內容

一、會議目的:

香港理工大學在過去多年來連續舉辦這個研討會，其宗旨在擴展有關海運、港埠與物流領域的學術研究，以及促進相關實務應用之發展。然而本人此次參予這個研討會，其目的主要是將個人近期對海運市場中，有關出租貨櫃與航商自有櫃間之選擇行為，來進行初步之探討。

於海運相關文獻之研究中，一直缺乏有關貨櫃航商選用自有櫃與租賃櫃決策分析之研究。然而此一課題，卻是極重要且具理論意涵與實務應用價值。然由於海運相關學術研究中，尚沒有研究者以經濟學生產理論模型，來針對貨櫃航商之租櫃與造櫃決策行為進行分析。而文獻上，與貨櫃租賃相關之研究，則多集中在有關貨櫃搬移之作業分析方法的探討。相對的，藉由生產函數之觀點，來分析自有櫃與租賃櫃間之替代性；以及航商選櫃行為之決策，於目前海運相關文獻上仍付之闕如。而此次本人發表之論文，乃是以經濟學理意涵與具實務操作可行性之理論模型，來解析不同貨櫃對運輸服務提供之貢獻差異，以及彼此間替代彈性之實證研究。

事實上，透過本研討會論文之探索，則將有助本人了解於國際貨櫃航運產業環境變動下，貨櫃航商在貨櫃建造與貨櫃租賃行為上之決策依據。本人相信將可完成提供撰寫一篇期刊論文之研究成果。而此一論文之研究內容，將可提供研究者與業者對有關航商貨櫃選擇決策與租賃產業發展內涵等課題上，有更進一步認識。所以未來此一論文之研究成果，將具相當之學術與實務參考價值。而本人預計未來完成之學術論文，將可能投稿於：Transportation research part E、Journal of transport economics and policy、Transportmetrica 或 maritime management and policy 等國際期刊。

再者，此次研討會有為數眾多之國際海運與物流學者與業者參與，研討會期間個人亦認識了不少學術界與企業界精英。同時，此次研討會全程有多位國際重量級海運、港埠與物流學者參予並發表當前產業之趨勢報告，是一個寶貴及難得之學習經驗。

二、會議過程:

此次研討會全程有多位國際重量級海運、港埠與物流學者參予並發表當前產業之趨勢報告，是一個寶貴及難得之學習經驗。此外此次研討會有為數眾多之國際海運與物流學者與業者參與，研討會期間個人亦認識了不少學術界與企業界精英。

本論文於發表過程中，得到不少與會人員的回饋，包含多項問題之澄清，以及未來論維發展演議方向之討論，因此對於後續論文的修正有相當大的幫助。本人相信藉由所獲得之認識與啟發，將可使筆者可深入研究此類議題。事實上，藉由此次研討會之論文發表,與會學者對本人此一研究課題極感興趣。在本人進行報告期間，計有五、六位學者對本人論文提出問題與建議，同時亦有提供具實務價值之見解。其中，與會學者所提之問題中，最主要是有關:國際利率因素，對自有櫃持有人與出租櫃持有人之影響是否具一致性；研究論文結論所認知之未知因素(unknown factors)確是值得細究與探討，而且這其中除屬市場價格與成本因素外，應是屬航商與貨櫃租賃商間之策略思考因素。

而有關上述與會學者所提出之問題，我個人於現場就各個問題一一提出我個人見解，例如:在利率問題上，我個人認為航商與貨櫃租賃商所承擔之利率成本應是一致的，故利率所扮演決定出租櫃與租賃櫃比例之決定因素上，應該不是主要因素。而本人對此一問題之回應，亦或提問人認同。另外，與會學者亦提供是否有策略競爭之思考，我個人則相當認同此一問題之思考，同時亦提出我的觀點:當航商提高自有櫃數量時，則其面對區域市場波動而致缺櫃之情況將獲得改善，進而其依賴貨櫃出租商之情況亦將減少，如此將有利貨櫃航商壓低租賃櫃之日租金水準。

過去數年來，香港理工大學物流及航運系投入極大人力與物力，舉辦此一國際研討會。每年會議期間都邀集多位國際海運研究知名學者與會並進行專題報告，因此本人在參與此次會議之其間中，可說收益良多。同時在進行論文發表時，個人不論在論文報告技巧、問題回覆思考上，亦皆有相當之進步與收穫，因此本人極盼望明年能繼續參與此一研討會。

參、心得及建議

IFSPA,2013,乃是香港理工大學物流及航運系連續多年投入極大人力與物力,所舉辦此一國際研討會。每年會議期間,大會都會邀集多位國際海運研究知名學者與會並進行專題報告,因此本人在參與此次會議之其間中,可說收益良多。同時在進行論文發表時,個人不論在論文報告技巧、問題回覆思考上,亦皆有相當之進步與收穫。因此透過本次研討會論文之發表,將有助本人參與國際會議之經驗,同時對本人之學術能力之提升亦有相當之助益。

再者,透過會議中與其他學者間之問題提問與對答過程,其不僅將增加本人對航商貨櫃投資與租賃行為、未來貨櫃租賃產業經營與發展模式等問題之體會與認知,另外亦可增進本人之學術視野。事實上,參與此次之國際研討會,對本人而言實在是獲益良多。而本人亦提出以下之建議:

1. 校方應更積極鼓勵學校教師與學生,參與國際學術研討會,以提升學術研究水準。
2. 校方應更積極鼓勵國際學術交流,邀請國際知名學者來校開課、互訪,或短期交流,以提升本校在國際學術之地位。

此外,本人亦相信透過國際研討會之參與,期將有助學術專業知識之傳達與增進,同時亦將有助國內研究生或準研究生更順利進行研究或啟發研究靈感,因此本人希望同儕及莘莘學子能多多參與此類活動。

肆、附件

一、論文發表過程照片

以下為本人論文報告時之照片

以下是本人論文報告結束後，接受與會學者提問之照片。

二、發表論文全文

論文被接受發表之大會證明文件

Dear Prof. Wu,

Thank you for your interest in the IFSPA 2013 conference and your full paper submission with us. We are pleased to confirm that your paper with the title

Paper Code: M27
Paper Title: The Elasticity of Substitution between Owned and Leased Containers

has been accepted for conference presentation and publication.

You are reminded to send us your finalized full paper also, if any, by 20 May 2013.

For enquiries, please feel free to contact us at ifspa.2013@polyu.edu.hk.

We look forward to welcoming you to Hong Kong in June.

Best regards,
Violette
IFSPA 2013 Organizing Committee - Secretariat
http://www.icms.polyu.edu.hk/ifspa2013/

所發表之論文全文

The Elasticity of Substitution between Owned and Leased Containers

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Abstract

In shipping practice, the utilizations of owned and leased containers are generally regarded as homogenous factor inputs and perfect substitution in providing container shipping service. In economics theory, the characteristic of perfect substitution implies an extremely price-sensitive pattern of factor input utilization. To follow the input ratios and price ratios of owned to leased containers, the former one shows a relatively stable pattern, but the latter one presents a trend with gradually decreasing rental rates of leased containers in recent years. Obviously, the practical observations on the pricing behavior of international container leasing market and the theoretical implications of the production function with perfect substitution are contradicted. The paper shows that the substitution between leased and owned containers is not perfect even though these two kinds of containers are homogeneously treated in shipping operation. By contrast, a fixed proportion production function is verified. Given a production function with fixed proportion technology, theoretically, it implies that the optimal combination between owned and leased containers will be located at a fixed ratio which is completely determined by some exogenous factors, other than the price ratios of owned and leased containers. As a consequence, the result suggests that some unknown factors not included in the production function may play the key roles on determining the combination between owned and leased containers in the operation of container shipping.

Keywords: container leasing, container shipping, elasticity of substitution, perfect substitution, fixed proportion technology

1. Introduction:

In international container shipping industry, it is a critical and complicated issue for carriers to determine a proper stock of containers for maintaining their operations and services along the port network they call. In practice, shipping lines need to keep a container fleet to support their ongoing operations, and prefer to buy a relatively fixed proportion of owned containers, irrespective of the whims of the market (Containerisation International Yearbook, 2007, p. 15). Due to the tremendous burden of capital cost associated with holding required amount of containers by container carriers, there are only a few carriers, especially in the early stage of containerization, able to afford the costly expenditure on expanding their containers fleet without sacrificing the growth of containerships fleet.

However, the fluctuations of market demand have brought an extreme difficulty for carriers to remain the balance between the demand and supply of containers. Facing with a volatile transportation demand in global container shipping, an aggressive attitude toward the development of containers fleet may lead to a number of idle containers scattered at the ports called and a huge capital burden for holding excessive containers. In contrast, a conservative attitude may incur a loss of business opportunities due to containers shortages. Therefore, a development strategy of container fleet by mixing with leased and owned containers has been widely adopted by container shipping lines to support transportation demand and to hedge against the risk of capital loss as holding too many owned containers or suffering devalued container price under a low-demand market condition.

In addition, Theofanis and Boile (2009) and Rodrigue (2009) also indicate that the empty container reposition caused by the trade imbalance between the eastern and western hemisphere after 1980s is a highly cost-consuming problem for container shipping lines and leasing companies. Since the beginning of containerization in the 1970s, as a consequence, the container leasing industry has emerged to offer an alternative tool in the management of containers fleet, enabling shipping companies to cope with temporal and geographical fluctuations in the demand (Rodrigue, 2009). Obviously, it will be helpful for shipping lines, container leasing companies and researchers to foresee the market development in global container leasing industry if the factors on determining the combination of leased and owned containers among container shipping lines are discovered.

The purpose of this paper is mainly to investigate the elasticity of substitution between owned and leased containers. By utilizing industry-specific data with the viewpoint of global container shipping industry, this study has applied a production function with constant elasticity of substitution (CES) to analyze the elasticity of substitution between owned and leased containers. Different from the practical observation viewing owned and leased containers as a pair of homogenous factor inputs in shipping operation, interestingly, the finding shows that a fixed proportion, but not perfect substitution, production function is a proper function form to describe the behaviors of shipping lines on holding a container fleet mixed with owned and leased containers.

2. Practical observation and theoretical implications

2.1 Observation on container leasing market:

On the purpose of delivering cargos, it is generally indifferent for a container shipping line to use owned or leased containers to load cargoes in transportation. And therefore, the two kinds of containers can be regarded as perfect substitution in shipping practice. In literature, Wang (2012) points out that the perfect substitution between owned and leased containers has benefited the shipping lines by utilizing and expanding their own container fleet to erode the market power of container leasing companies. In turn, any attempt by leasing companies to exert market pressure on rental rates will simply result in the purchase of more containers by shipping lines. Due to the sound financial structures among the huge container shipping lines and more friendly and accessible international capital market under a fairly low interest rate during the past decade, it has also facilitated most container shipping lines to purchase more containers for building up their own container fleet. As a result, the container leasing industry has experienced a gradual evolution with decreasing rental price per diem and lost market share to the carriers own containers since 1990s.

Compared with the rising trend on the price ratios of owned to leased containers, as shown in Figure 1, the input ratios of owned to leased containers present a relatively stable level around 1.2. It demonstrates that the global container fleet in the container shipping industry is mixed with a roughly fixed proportion of owned and leased containers, regardless of the per diem rates of leased containers gradually becoming cheaper than the ones of carriers own containers.

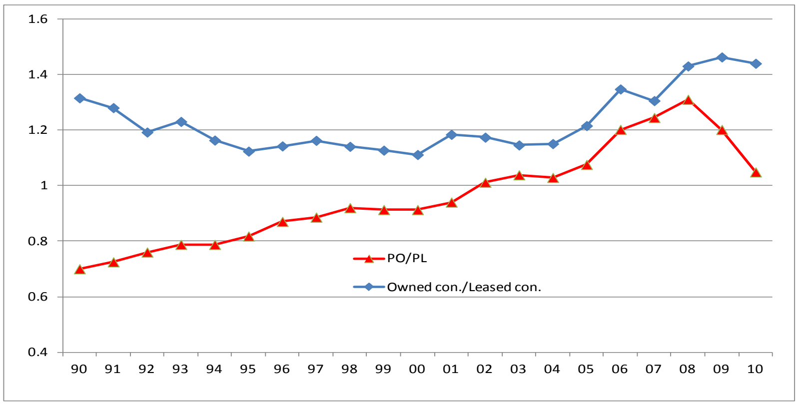

Figure 1

2.2The elasticity of substitution:

In economics, neoclassical production theory recognizes the possibility of substituting one factor of production for another. Under a production technology, an isoquant is the set of all possible combinations of inputs that are sufficient to produce a given level of output. And, the elasticity of substitution (σ) is generally used as an index to reflect the geometric expression for the curvature of an isoquant. Graphically, the index shows changes in relative factor demand with respect to changes in the marginal rate of technical substitution. Meanwhile, it is also equivalent to the elasticity of input ratio with respect to input prices ratio. Therefore, the elasticity of substitution in a production function with two factor inputs can be expressed as:

$$\sigma = \frac{dX/_{X}}{dW/_{W}} \tag{1}$$

where $X = \frac{X_1}{X_2}$, $W = \frac{W_1}{W_2}$. And, W_1 and W_2 are the factor prices corresponding to input factors, X_1 and X_2. By definition, the value of σ varies between 0 and ∞. Following with economics theory, each of the extreme values, as shown in Figure 2, implies a special case of production pattern with a L-shaped or straight line isoquant cure, respectively. In other words, the production function presents a pattern with fixed proportion[1] or perfect substitution between factor inputs, as σ→0 or σ→∞, respectively.

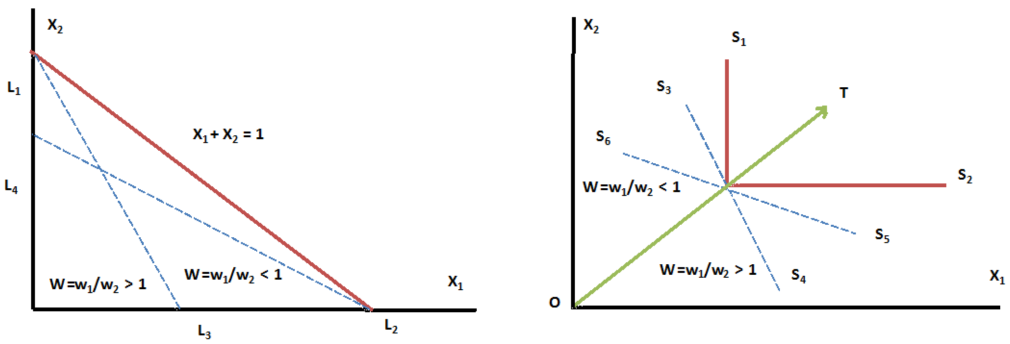

Figure 2

[1] By definition, an isoquant curve with a zero value of σ implies no possibility of substitution between different factor inputs, conditional on producing a given level of output. Conceptually, this type of isoquant is just like the case of perfect complement in consumer theory. Thus, the fixed proportion can be viewed as a complementary case in the usage of the two factor inputs.

According to the theory of production in economics, the optimal input combination for an L-shaped isoquant curve, as shown in Figure 2, must be located at the points along the arrow line OT, which is completely determined by an exogenously given ratio of factor inputs. In fact, it reflects an isoquant with zero elasticity of substitution, and therefore indicates that there is no possibility to substitute one input factor with the other one at the optimal point even if the input price ratio has been greatly changed. Apparently, the price ratio plays no role on determining the optimal combination of factor inputs if the production function is characterized with fixed proportion technology.

In perfect substitution case, the optimal input combination is always located at either one of the corner points along the straight line isoquant, and therefore totally dependent on the price ratio of the two factor inputs. For example, an isoquant curve specified as $X_1+X_2=1$ and shown in Figure 2 implies that the firm will merely use input X_1 to produce the given amount of output if the price ratio, $W = \frac{W_1}{W_2}$, is less than one. Under a production technology with perfect substitution, the most cost-saving input combination for the firm is to use input X_1 only while the price of the input X_1 is less than input X_2. Accordingly, it implies that container shipping lines will completely utilize the type of containers with lower price if the two types of containers are perfect substitution.

With reference to the curves shown in Figure 1, it shows that the price ratios of owned to leased containers, P_O/P_L, have been over one since 2002 to indicate a relatively higher cost for a container carrier holding its own containers. Nevertheless, the more expensive owned containers have never forced shipping lines to completely abandon developing their own container fleet. Furthermore, the less expensive leased containers did not make container leasing companies to earn a dominant role with share over half amount of global containers either. On observing the coexistence of owned and leased containers in the container shipping industry, obviously, it is implausible to argue that the two kinds of containers are perfect substitution.

3. The estimation of elasticity of substitution

3.1 Production function with constant elasticity of substitution:

To follow the production theory in economics, it is well recognized the possibility of substituting one factor of production for another. In order to investigate the extent of substitution between the owned and leased containers in the international container shipping industry, it is assumed that there are only two inputs, owned containers (X_1) and leased containers (X_2), used to support a given output level (Y), measured by the unit of TEU (twenty-foot equivalent unit). In addition, a time variable (t) is also included into the function to represent the exogenously disembodied technological change in container shipping transportation. Accordingly, the production function of shipping industry can be specified as:

$$Y_t = f(X_{1,t},\ X_{2,t},\ t) \qquad (2)$$

In order to know the substitution between the factor inputs of production function, it is necessary to specify a production function. In empirical studies, the Cobb-Douglas (CD) function is the most commonly utilized form in the specification of the production function because it can be easily linearized to estimate important production parameters. However, a priori condition with a unitary elasticity of substitution is the most suspicious idea, while assessing the adequacy of function form in the studied cases. Hence, the strong assumption to restrict a unitary elasticity of substitution under a CD production function is still questionable and proved to be an improper specification of production function in some empirical studies (Hsing, 1996; Bonga-Bonga, 2009). Since the main goal of this study is focused on investigating the substitution between owned and leased containers in container shipping industry, the unity of elasticity of substitution implies the inadequacy of CD production technology. Instead, a CES production function is applied in this study to investigate the substitutability between owned and leased containers in international container shipping industry. In recent years, the CES production technology has gained much popularity in empirical studies, and can be addressed a wider range of elasticity of substitution embodied in a production function.

In this study, a CES production function will be selected to investigate the substitution between the owned and leased containers in container shipping industry. It is assumed that the production function at time *t* is specified as:

$$Y_t = A_0 e^{\gamma t}\left[\alpha X_{1,t}^{-\rho} + (1-\alpha) X_{2,t}^{-\rho}\right]^{\frac{-h}{\rho}} \tag{3}$$

where A_0, γ, ρ, and h are scale, technological change, substitution and return to scale parameters. And, α and (1-α) are factor distribution parameters. Based on the definition and theoretical derivation, the elasticity of substitution corresponding to equation (3) can be measured by

$$\sigma = \frac{1}{1+\rho} \tag{4}$$

Hence, the range of values for ρ is $-1 < \rho < \infty$. By equation (4), the CES function is a L-shaped isoquant to represent a fixed proportion production function as $\rho \to \infty$ and $\sigma \to 0$. And, the isoquant curve becomes a straight line to represent a perfect substitution case as $\rho \to -1$ and $\sigma \to \infty$. When $\rho \to 0$ and $\sigma \to 1$, the CES function is reduced being a CD function with a constant elasticity of substitution equal to one. Therefore, the CD function is a special case of CES function.

3.2 Estimation approach:

Other than the estimation of CD function only needs a logarithmic transformation for its linearization, the CES function is non-linear and cannot be easily transformed to be linear regression equation. Thus, the standard linear estimation methods cannot be applied to the estimation of the parameters in a CES function[2]. By utilizing the marginal production of factor input, in this study, an indirect estimation with two-step approach is applied to estimate the

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[2] Kmenta (1967) provides an approach that directly estimates the CES production function by approximating the non-linear CES specification with Taylor transformation around $\rho = 0$, and linearizing it by dropping the terms involving powers of ρ larger than one. However, the application of Kmenta approximation is limited because it only returns reliable results if ρ is close to its point of approximation, i.e. zero (Thursby and Lovell, 1978). Hence, the linearization of non-linear CES production function by employing Kmenta approximation is only applicable for elasticities of substitutions in the neighborhood of unity. In addition, other problems with Kmenta approximation include that it is only applicable to a two input case and presupposes that the elasticity of substitution is unity (Hoff, 2004).Also, the estimation of CES function by using the non-linear methods cannot either perform very well due to the problems, a large flat of surface of objective function to cause local minima, the discontinuity of CES function and considerable rounding errors at specific parameters (Henningsen and Henningsen, 2012).

parameters of the CES production function (Erol, 2006, Xu, 1999, Fitzroy, 1995).

In the first step, the marginal productivity of factor input is derived as follows:

$$\frac{\partial Y}{\partial X_1} = A_0 e^{\gamma t}\left[\alpha X_1^{-\rho} + (1-\alpha)X_2^{-\rho}\right]^{\frac{-h-\rho}{\rho}} h\alpha X_1^{-(\rho+1)} \tag{5}$$

$$\frac{\partial Y}{\partial X_2} = A_0 e^{\gamma t}\left[\alpha X_1^{-\rho} + (1-\alpha)X_2^{-\rho}\right]^{\frac{-h-\rho}{\rho}} h(1-\alpha) X_2^{-(\rho+1)} \tag{6}$$

Under a competitive shipping market, the first order condition for profit maximization implies that the optimal condition for the demand of the owned and leased containers can be expressed as:

$$\frac{\partial Y}{\partial X_1} = MP_{X_1} = \frac{W_1}{P_Y} \tag{7}$$

$$\frac{\partial Y}{\partial X_2} = MP_{X_2} = \frac{W_2}{P_Y} \tag{8}$$

Dividing equation (7) by (8), the ratio of owned to leased container prices is derived as:

$$\frac{\alpha X_1^{-(\rho+1)}}{(1-\alpha)X_2^{-(\rho+1)}} = \frac{W_1}{W_2} \tag{9}$$

Next, by taking natural logarithm to equation (9), a linear regression equation can be developed as:

$$ln\frac{X_1}{X_2} = \beta_0 + \beta_1 \ln\frac{W_1}{W_2} \tag{10}$$

where $\beta_0 = -\frac{1}{\rho+1} ln\left(\frac{\alpha}{1-\alpha}\right)$ and $\beta_1 = -\frac{1}{\rho+1}$.

In fact, equation (10) is utilized as the first step in the linearization of the CES function. At this step, the elasticity of substitution, σ, is estimated as well as the distribution parameter α. In the meantime, the hypothesis for testing the elasticity of substitution corresponding to the production function specified in equation (3) can be set as:

$$H_0: \; H_0: -\beta_1 = \frac{1}{\rho+1} = \sigma = 0 \tag{11}$$

Statistically, this hypothesis testing implies a fixed proportion production function if the hypothesis can't be rejected.

Given the estimated values for the two parameters, σ and α, furthermore, a composite explanatory variable, Z_t, is constructed and expressed as:

$$Z_t = \left[\alpha X_{1,t}^{-\rho} + (1-\alpha)X_{2,t}^{-\rho}\right]^{\frac{-1}{\rho}} \tag{12}$$

By replacing equation (12) into equation (3) and taking a natural logarithm transformation for the resulting equation, the second step for linearizing a CES function is performed to construct a linear regression equation as:

$$lnY_t = lnA_0 + \gamma t + h * lnZ_t \tag{13}$$

Obviously, the parameters, A_0, γ, and h, in the CES production function can be estimated by equation (13).

3.2 Data sources and empirical results:

In the empirical study, two regression equations specified in equation (10) and (13) will be estimated for computing the elasticity of substitution and other parameters in the production function. On estimating the parameters in equation (10), two ratio variables respectively representing the input prices (W_1/W_2) and factor input usages (X_1/X_2) should be measured at first. Hence, there are only four variables needed to perform the regression estimation for equation (10) and (13). In this study, the discounted present values of newly built containers with 8-year life time and zero residual value are computed to measure the holding cost of containers owned by container shipping lines. The sample period spans from 1990 to 2010. All the data for the four variables are mainly drawn from the relevant issues of the *Containerisation International Yearbook* and *Review of Maritime Transport*.

Initially, the ordinary least square (OLS) technique is utilized to estimate the parameters in equation (10) and (13). Since the residual errors of the OLS estimation reveal a significantly serial correlation, an autocorrelation model is applied. The estimated parameters of the two equations along with their *p-value*s are reported in Table 1. The R^2 values for equation (10) and (13) are 0.76, 0.98, respectively. In equation (10), the estimate of constant term reveals statistically significant. However, the key parameter, β_1, which represents negative elasticity of substitution, is not significantly different zero, and therefore implies that the elasticity of substitution is statistically equal to zero. Accordingly, the argument of perfect substitution between the owned and leased containers is not supported by this empirical result. By contrast, it significantly suggests that the CES production function specified in equation (3) is developed from a fixed proportion production function with L-shaped isoquant. Associated with the theoretical implication of the fixed proportion production function, surprisingly, the empirical result implies that the utilization of factor inputs is completely unrelated with the prices ratios of owned and leased containers.

In fact, the finding reflects the relationship between the two curves shown in Figure 1 that the increasing input ratios of owned to leased containers are associated with increasing price ratios. Since 2004, in particular, the uprising trend of input ratios is unexpectedly corresponding with an increasing trend of price ratios. Therefore, it illustrates that the utilization of factor inputs does not follow the theoretical implication to present a negative relationship between the input and price ratios if the two types of containers are substitute each other. Implicitly, the result indicates that some unknown factors not included in the production function may play the key roles on determining the combination of owned and leased containers in the global operation of container shipping.

In equation (13), the estimates of parameters show to be significant in technical parameter, γ, but insignificant in scale parameter, h. The result indicates that the growth rate of technical progress in the operation of global container shipping is significant with an annual rate of 7 percent. Surprisingly, the insignificant scale parameter presents an outcome to show the ineffectiveness of expanding the scale of global container fleet on the productivity growth of international container shipping industry. Obviously, this finding implies that an over-capacity of global container fleet has been deployed into shipping market by the container shipping lines and leasing companies. Given the higher container price under the more expensive steel price, in fact, the persistently low cost of capital caused by the historically low interest rate during the past several years may have outpaced the disadvantage of higher container prices, and push container shipping lines and leasing companies eager to expand their container fleet. Under a fixed proportion technology of production, in addition, this finding may provide some clue to investigate the factors for determining the mix of owned and leased containers among the shipping lines and leasing companies.

Table 1

Equation (10)			Equation (13)		
Variable	Coefficients	P-value	Variable	Coefficients	P-value
β_0	0.303	0.003	γ	0.07	0.001
β_1	0.207	0.235	h	0.00001	0.359
R^2	0.76		R^2	0.98	

4 Conclusion

In shipping practice, the utilizations of owned and leased containers are generally regarded as homogenous factor inputs and perfect substitution in providing container shipping service. In theory, the characteristic of perfect substitution implies an extremely price-sensitive pattern on the utilization of factor inputs. By observing the input ratios and price ratios of owned to leased containers, however, the former one shows a relatively stable pattern and latter one presents a trend with a gradually decreasing rate of leased containers in the past two decades. Accordingly, the theoretical implication for the production function with perfect substitution and the practical observation on the price ratios and utilization ratios of owned and leased containers are contradicted.

By applying a production function with CES technology, this paper finds that the substitution between owned and leased containers is not perfect. In contrast, it follows a pattern with fixed proportion technology. Given a production function with fixed proportion technology, theoretically, it implies that the optimal combination between owned and leased containers will be located at a fixed ratio which is completely determined by some exogenous factors, except the price ratios of owned and leased containers. In other words, the finding suggests that some unknown factors not included in the production function may play the key roles on determining the utilizations of owned and leased containers in the global operation of container shipping.

In the further study, this paper can be extended to investigate what and how the key factors have played on determining the fleet developments of owned and leased containers for container shipping lines. And therefore, the findings of the study will be very helpful on forecasting the individual growth of the leased and owned containers in the future.

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