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UNVEILING SUPPLY CHAIN INTEGRATION AND ITS VALUE IN CONTAINER SHIPPING

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ABSTRACT: Integrated supply chain management is becoming increasingly recognised as a core competitiveness for business. This is putting increased demands on freight transport services. Transport services should contribute to adding value, and the value added by transport can be significant if the operations take place in a well organised, efficient and market responsive transport system. This study aims to develop an original modelling approach for estimating supply chain value, and empirically focuses on a major world trade facilitator - container shipping. The paper presents the multivariate ordered probit/ logit models and the empirical results. Based on comprehensive literature review and conceptual theory building, a normative model for managing container shipping supply chains with the aim for better synchronisation and ultimately for value (i.e. profit for commercial setting) maximisation is proposed. A survey instrument is used to empirically verify the model with the data given by professionals from the world's top thirty container shipping lines. It is found that the level of supply chain integration is positively related to the supply chain value and profit. Overall, customer service activities are the most influential factor in affecting the supply chain value. Hence, we suggest firms to devote more resources and efforts in: 1) promoting supply chain collaboration; 2) upgrading customer service activities at strategic, tactical and operational levels. Other implications and recommendations are generated according to the empirical results.

KEYWORDS: ordered probit, ordered logit, supply chain value, supply chain integration, container shipping, customer service.

1. INTRODUCTION

T RADITIONALLY, the maritime transport industry is comprised of a well defined series of related but separated activities, where each participant

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is responsible for a limited part of the process. However, this mode of operation is no longer sufficient in managing global supply chains competitively in the modern era. Integrated supply chain management (SCM) is becoming increasingly recognised as a core competitiveness for business. This is putting increased demands on freight transport services. Transport services should contribute to adding value, and the value added by transport can be significant if the operations take place in a well organised, efficient and market responsive transport system. The study looks into a major world trade facilitator, container shipping, from an integrated perspective and investigates supply chain integration (SCI) in container shipping. SCI refers to integration of processes across organisations in a supply chain. Thus in container shipping, major members in the chain include shippers, liners and port/terminal operators. This study aims to develop an original modelling approach for estimating the supply chain value generated by container shipping. The paper estimates the importance of individual supply chain players' contribution and their integration level in determining the overall value of the supply chain. A model for strategic, tactical and operational management will be estimated respectively for comparison.

After the introduction, the next section presents the literature review and theoretical basis. Section 3 explains the research methodology. After that, empirical results and hypothesis testing are given in sections 4 and 5. Section 6 will discuss the findings and implications. The last section concludes and provides future research suggestions.

2. LITERATURE REVIEW AND THEORETICAL BASIS

2. 1. *Literature Overview and Gaps Identified*

Past literature on the supply chain aspects of container shipping can be grouped under three categories. The first group of papers are about shipping lines in the supply chain (Evangelista and Morvillo 1999, 2000; Evangelista et al., 2001; Heaver, 2002a, 2002b; De Souza et al., 2003; Fremont, 2009). The second group of papers study ports/ port community in the supply chain (Robinson, 2002; Carbone and Martino, 2003; De Souza et al., 2003; Marlow and Paixao, 2003; Paixao and Marlow, 2003; Bichou and Gray, 2004; Song and Panayides, 2008; Weston and Robinson, 2008; Tongzon et al., 2009). We observe that studies on ports are stronger in terms of research constructs and conceptualisation. The third group of papers specifically research on an integrated transport chain (Frankel, 1999; Islam et al., 2005). However, so far no paper empirically investigates the integrated supply chain approach in container shipping.

Other papers on maritime economics, management science, generic SCM

and SCI related to our topic concerned were also reviewed, such as those about shipper-carrier relationship and partnership (e.g. Lu, 2003a, 2003b), supply chain performance in transport logistics (Lai et al., 2002, 2004) and supply chain integration (e.g. Weng, 1995; Johnson, 1999; Lee and Whang, 2001; Frohlich and Westbrook, 2001; Fawcett and Magan, 2002; Vickery et al., 2003; Chen and Chen, 2005; Paulraj et al., 2006; Kim, 2009). Particularly, four comprehensive review papers on SCM and SCI (Power, 2005; Fabbe-Costes and Jahre, 2007; Giunipero et al., 2008; Van der Vaart and Van Donk, 2008) covering more than 490 studies were consulted. They provide good references for the theoretical basis, as well as our modelling and empirical efforts.

It is concluded that SCI is an area of growing importance but has not been well connected to shipping in the literature. Publications in managing container shipping as an integrated chain are very limited (Lam and Van de Voorde, 2011), despite the importance of this research topic. In a broader sense, there are a number of studies addressing the significance of maritime transport in supply chains. However, most of the papers mainly address on a single entity, shipping lines or ports, and study how it relates to the supply chain. What we attempt to accomplish is a more integrated approach, which has been hardly done in a comprehensive manner. Our study is a rigorous attempt to fill this gap.

2. 2. Conceptual Theory Building and Model Building

After reviewing the literature on the research topic, this section illustrates model building.

To follow a scientific model building process, we have consulted literature in conceptual theory building (particularly Meredith, 1993; Handfield and Melnyk, 1998). A well designed model should be built on an appropriate base of theory. Accordingly, the theoretical basis for SCI was traced to the Value Chain Model (Porter, 1980). Porter advocated that vertical (buyer-supplier) cooperation is integral to firms' value generation and competitive advantage. Inter-firm coordination along the supply chain is the key to the effective implementation of SCM. Bowersox et al. (1999) also pointed out that SCI's objective is to provide maximum value to its customers. In theory, therefore, SCI positively contributes to the value created by a supply chain. As such, it is envisaged that SCI in container shipping would enhance its value. Hence, a normative model for managing container shipping supply chains (CSSC) with the aim for better synchronisation and ultimately for value (i.e. profit for commercial setting) maximisation (Nagurney, 2006; Chopra and Meindl, 2007) is proposed.

Model formulation is also developed based on the literature. Three levels of decisions, namely strategic, tactical and operational, are included since

SCI involves information sharing, planning, coordinating and controlling materials, parts and finished goods at these three levels according to Stevens (1989). Comprehensive collaboration among supply chain members mean that they work together at the three levels. Regarding the areas for them to collaborate in, four areas of activities are selected, namely transportation, customer service, inventory management and order processing. We firstly consider the transportation function and freight handling since this is the primary purpose for the existence of shipping lines and terminal operators. Transportation related attributes such as freight rate, cargo care, transit time, service frequency and reliability are often found to be significant (Cullinane et al. 2002; Lam and Dai, 2012). We suggest that both front-end and back-end activities should be considered. Customer service and quality are major concerns for shippers and the primary value sought by many shippers has shifted from price to quality service performance (Lagoudis et al., 2006). The bottom line for shippers is the need for information about services, shipments, bookings, and documents (Durvasula et al., 2000 and 2004). Performance on important service attributes indicated by Lu (2003a) such as accurate documentation and availability of cargo space would be improved with closer collaboration among the supply chain members in container shipping. Hence, customer service, inventory management and order processing are also included as areas of SCI. It is a 3x4 matrix model having 12 cells. Examples of the cell activities are shown in figure 1. Supply chain value Z is estimated by function f as shown below.

$\diagdown$ n m $\diagdown$	Customer service 1	Inventory 2	Transportation 3	Order processing 4
Strategic level 1	11 Setting desirable service level	12 Empty container repositioning policies	13 Selecting carriers; Selecting ports of call	14 Information system design; Shipping demand forecasting
Tactical level 2	21 Collecting customers' feedback	22 Determining safety stock level	23 Seasonal capacity adjustments	24 Assessing backorders
Operational level 3	31 Handling shippers' requests	32 Replenishment quantities and timing	33 Sea transportation; Loading and unloading	34 Booking; Documentation

FIGURE 1. Model for managing container shipping supply chains with examples of cell activities.

$$Z = f(x_{mni}, y_{mnij}, a_{mni}, b_{mnij}) = \sum_{m=1}^{3} \sum_{n=1}^{4} (a_{mni} x_{mni} + b_{mnij} y_{mnij}) \qquad [1]$$

Z is overall container shipping supply chain value generated by all firms i

x_{mni} is individual contribution of cell mn of firm i

y_{mnij} is integration level of firm i with supply chain member j in each cell mn

a is parameter of variable x

b is parameter of variable y

m is symbol for the level of activity, m = 1, 2, 3

n is symbol for the area of activity, n = 1, 2, 3, 4

j is supply chain member, which can be downstream, denoted by d (shipper in the empirical test), or upstream, denoted by u (port/ terminal operator in the empirical test)

With liners as focal firm in this paper, x_{mni} represents liner's activities; y_{mnij} represents liner's integration level with other supply chain members.

2. 3. Statement of Hypotheses

A survey instrument was used to empirically verify the model with the data given by professionals from container lines. This section explains the four hypotheses to be tested. Conceptualised mainly with reference to shipping and transportation literature e.g. Evangelista et al. (2001), Lai et al. (2004) and Durvasula et al. (2004) on the four logistics activities (customer service, inventory, transportation and order processing), Condition 1 of the normative model states that the cell activity has to perform well individually, so that it contributes to the CSSC value (Z). Hence, the first hypothesis is:

• *Hypothesis 1*: Higher individual contribution of the cell activities (X_{mni}) has a positive effect on the supply chain value (Z).

Condition 2 of the model states that each cell activity should be integrated with the supply chain members. This will further contribute to the increase in Z. Conditions 2 and 3 (to be explained below) were developed based on the numerous SCM and SCI papers such as Weng (1995) and Lee and Whang (2001) who demonstrated that companies can attain higher profits with supplier-buyer integrated supply chain. Frohlich and Westbrook (2001) and Wilding and Humphries (2006) also addressed the need for closer, long-term relationships within the supply chain for performance improvement. It is worth noting that relatively few papers examined both downstream and upstream

relationships (Van der Vaart and Van Donk, 2008). This study categorises supply chain members into both downstream partners and upstream partners, thus having Y_{mnid} and Y_{mniu} as independent variables. This suggests a positive association between the level of integration with supply chain members and Z. We set the second and the third hypotheses as:

  • *Hypothesis 2*: Higher level of integration with the major shippers (Y_{mnid}) has a positive effect on the supply chain value (Z).

  • *Hypothesis 3*: Higher level of integration with the major terminal operators (Y_{mniu}) has a positive effect on the supply chain value (Z).

Condition 3 states that the cell activities have to perform well coherently so to achieve optimisation. All cells are considered collectively. Thus the mathematical model includes the individual contribution of the cells (X_{mni}), the level of integration with the major shippers in the cells (Y_{mnid}), and the level of integration with the major terminal operators in the cells (Y_{mniu}) as the independent variables.

  • *Hypothesis 4*: The joint effect of X_{mni}, Y_{mnid} and Y_{mniu} in influencing the supply chain value Z is simultaneously larger than zero.

3. Research Methodology

Empirical data was collected by a survey in the form of interview conducted with the professionals from the top thirty container shipping lines in the world, based on Alphaliner (2007). The liner business is highly concentrated (Lam et. al., 2007). Referring to the slot capacity deployed in terms of TEU, the top thirty carriers accounted for a market share of 85.6%. With this high market share, the views from this group are considered representative of the major players in the liner industry. A pilot survey has been run before the actual field work. Two executives from top or middle management from each of the top thirty lines were approached for the formal survey. Totally, 54 interviews were conducted in 2007 and 2008. The interviewees represented their business unit and considered the major supply chains involved when they responded. Data for X, Y and Z and useful information in explaining the data were collected. The effective sample size was 53 since one sample was an outliner which will be explained later. Several measures have been taken to mitigate the concerns on non-response and response biases. In choosing a suitable data collection method, we have considered issues such as research objective, problem definition, research settings and constraints. Compared to one-way communication when completing the survey by the respondents, content validity was enhanced in a two-way communication environment,

where definitions and concepts could be clarified during the interviews. This is important for the current study as the research topic is relatively new. Another advantage of conducting interviews is being able to secure a high response rate. In order to gather a balanced view, interviews were performed with three global shippers and two global terminal operators in 2009 to verify the survey results.

4. EMPIRICAL FINDINGS

4. 1. *Basic Standpoint of the Interviewed Companies*

The respondents were asked if they considered their company as part of a container shipping supply chain. Out of the 54 responses, only one indicated that the company is not considered as part of a CSSC[1]. Most of the interviewees acknowledged the link between their company and the supply chain. The result is in line with our observation that the trend in container shipping is towards higher degree of vertical integration. The result also adds credit to our approach of studying container shipping from the supply chain perspective.

4. 2. *Importance of the Cells*

The survey results obtained from industry professionals enhanced the content validity of the postulated model. Before collecting data for X and Y, the respondents were asked to rate the importance of each cell in a CSSC in order to verify the relevancy of the proposed cells to the industry. The respondents could choose any value in a continuum numerical scale: 1 is "not at all important", 5 is "very important". The mean scores are all above 4.2 and the total mean is 4.49 (see table 1). The most important cell indicated by the respondents is X13, representing transportation at strategic level, with the mean score of 4.72. It is followed by X33, representing transportation at operational level (4.70) and X23, representing transportation at tactical level (4.69). They also have the lowest standard deviations reflecting relatively consistent opinion on their high importance. Comparatively, the least important cell is X22, denoting inventory at tactical level (4.22). We notice higher standard deviations towards lower ranking. This reveals dispersion of opinion in these cells' importance.

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[1] Due to the exceptional answer out of the 54 responses, this sample is considered an outliner and it is decided to exclude this sample for regression analysis. Therefore, the effective sample size for regression analysis is 53.

TABLE 1. Mean scores and ranking indicating the importance of the cells.

Rank		Cell	Mean score	St. deviation
1	X13	Transportation, Strategic	4.72	0.45
2	X33	Transportation, Operational	4.70	0.50
3	X23	Transportation, Tactical	4.69	0.51
4	X31	Customer service, Operational	4.61	0.66
5	X11	Customer service, Strategic	4.56	0.77
6	X34	Order processing, Operational	4.54	0.54
7	X21	Customer service, Tactical	4.53	0.80
8	X14	Order processing, Strategic	4.44	0.65
9	X24	Order processing, Tactical	4.41	0.64
10	X32	Inventory, Operational	4.25	0.97
11	X12	Inventory, Strategic	4.23	0.96
12	X22	Inventory, Tactical	4.22	0.98
Total mean			4.49	

Thus, we confirm that the 12 cells are considered important and should be included in the model. A lot of interviewees did indicate that all the cells are essential and cannot be ignored in container transport. Many also stated that the success or failure of the chain is determined by all the cells, not only some of the cells. The inputs from the interviewees strengthen condition 3 set in the model, stating that the cell activities have to perform well coherently so to achieve optimisation.

Although all the cells are rated as important, it is noticed that the ranking based on the average scores signifies a pattern which indicates a difference in the level of importance. In general, for the four areas of activities, transportation is the most important, followed by customer service, order processing and inventory. It may be explained by the fact that offering transportation solutions is the core activity of liner shipping companies. Hence, transportation is ranked first amongst the four activities. In the market driven and competitive business environment, customer service is highly emphasised, making it the second important. Order processing and inventory management are essential but not perceived as fundamental as transportation and customer service.

4. 3. *Supply Chain Value*

The respondents were asked to indicate the overall value generated by the chain (Z) based on financial estimation. The answer is a proxy to supply chain profit which is not directly observable due to data availability, i.e. in

the absence of revealed preference data, a stated preference methodology is used. Z can be regarded as ordinal realisations of the underlying continuous variable (Winship and Mare, 1984). The measurement scale is an ordered response scale: from not high at all to very high. There are 9 available ordered choices coded from 1 to 9. However, no respondent chose the lowest value 1. Hence, the number of observable ordered responses is 8.

4. 4. *Estimation Process*

Having considered various multivariate techniques, the most appropriate specification is ordered probit/ logit, also known as ordered response model mainly due to the feature of Z as explained above (Greene, 2008). The model can analyse the probabilities of observing the various choices of the dependent variable in response to the measurable independent variables. A constant term is not separately identified in ordered probit/ logit models (Winship and Mare, 1984; Washington et al., 2003; EViews, 2007; Greene, 2008). Hence, there is no constant term in the regression equations presented later in the paper. Correlation matrix indicates that the correlation coefficients are below 0.6. Thus, multicollinearity does not seem to be a problem in the data set. Estimation of parameters was started with the initial variables in the mathematical model. Inevitably, there was uncertainty regarding the appropriateness of the original model. Selecting a specification of ordered response model mainly involved two issues: (1) equation specification, that is, which independent variables to be included, and (2) error specification, that is, to select between normal distribution and logistics distribution for the error term. The former leads to ordered probit model while the latter leads to ordered logit model. After estimation, we evaluated the quality of the specification by utilising diagnostic and specification tests. Another round of specification, estimation and evaluation took place. The process was repeated until we obtained the model which was correctly specified based on the evaluation indicators.

We aim to estimate a model for strategic, tactical and operational management respectively. This allows deriving results for each level, performing comparison and drawing greater insights. The interviewees also validated that our model should include the three levels of management, as they are all important and cannot be skipped. Below are the ordered probit models for each of the three levels.

Model 1: final ordered probit model for strategic factors

Equation 4 and table 2 depict the estimation output of the final model for strategic factors.

$$Z = 2.3695^{*}X11 + 0.8414^{*}X13 + 0.6421^{*}X14 + 0.5152^{*}Y14U \qquad [4]$$

where
Z represents the ordered responses coded 2, 3, 4, 5, 6, 7, 8, 9

TABLE 2. Estimation output of Model 1: ordered probit.

	Coefficient	Std. Error	z-Statistic	p (2-tailed)	p (1-tailed)
X11	2.369544	0.476585	4.971925	0.0000	0.0000*
X13	0.841352	0.361058	2.330242	0.0198	0.0099*
X14	0.642074	0.339253	1.892610	0.0584	0.0292**
Y14U	0.515205	0.197942	2.602807	0.0092	0.0046*
		Limit Points			
LIMIT_3:C(5)	7.926468	2.107216	3.761582	0.0002	
LIMIT_4:C(6)	10.12192	1.851919	5.465640	0.0000	
LIMIT_5:C(7)	11.41357	2.033462	5.612877	0.0000	
LIMIT_6:C(8)	15.59899	2.597510	6.005364	0.0000	
LIMIT_7:C(9)	16.52883	2.672994	6.183638	0.0000	
LIMIT_8:C(10)	19.55311	3.151659	6.204069	0.0000	
LIMIT_9:C(11)	19.95615	3.175738	6.283939	0.0000	
Pseudo R-squared	0.604395	Akaike info criterion		1.753569	
Schwarz criterion	2.162497	Log likelihood		-35.46957	
Hannan-Quinn criter.	1.910823	Restr. log likelihood		-89.65900	
LR statistic	108.3789	Avg. log likelihood		-0.669237	
Prob(LR statistic)	0.000000				

Notes:
* significant at α of 0.01
** significant at α of 0.05

After the iterative estimation process, the variables in the final model are X11, X13, X14 and Y14U. It is found that variable X11 has a z-statistic of 4.9719 and a p-value of 0.0000, which is an extremely low probability. Its coefficient (2.3695) is the highest relative to other variables. Hence, X11 is the most significant variable at the strategic level. The limit points shown in table 2 are the threshold parameters μ of the probability distribution of Z, where

$$Z = 2 \text{ if } Z^\star \leq 2$$
$$Z = 3 \text{ if } 2 \leq Z^\star \leq \mu_3$$
$$Z = 4 \text{ if } \mu_3 \leq Z^\star \leq \mu_4$$
$$\cdot$$
$$\vdots$$
$$Z = 9 \text{ if } \mu_9 \leq Z^\star$$

The limit points are useful for calculating the probability of observing a Z value given the values of the independent variables, and for calculating the marginal effects of the coefficients, which cannot be directly obtained

(EViews, 2007; Greene, 2008). This will be discussed later in section 5. The other diagnostic statistics shown at the bottom of table 2 are satisfactory, judged by the reasonably high Pseudo R-squared (0.6044), reasonably low information criteria (Akaike info criterion, Schwarz criterion and Hannan-Quinn criterion) and highly significant LR statistic (108.38) (p= 0.0000). Residual tests, particularly Jarque-Bera test (Jarque and Bera, 1987), were also conducted to examine the error term of the model.

Model 2: final ordered probit model for tactical factors

As shown in equation 5, the variables in model 2 are X21, X22, X24, Y21D, Y21U and Y22U. Referring to table 3, variable Y21D has a z-statistic of 3.2731 and a p-value of 0.0006, which is considered a very low probability. We assess other variables similarly. Variables X21 and Y21D are the most significant variables at the tactical level. The interpretation of limit points and diagnostic statistics is similar to model 1, so such explanation will not be given for models 2 and 3 due to space limitation.

$$Z = 2.5668 * X21 + 0.8236 * X22 + 1.3251 * X24 + 2.1769 * Y21D * \\ + 0.8287 * Y21U + 0.8059 * Y22U \tag{5}$$

TABLE 3. Estimation output of Model 2: ordered probit.

	Coefficient	Std. Error	z-Statistic	p (2-tailed)	p (1-tailed)
X21	2.566772	0.867364	2.959279	0.0031	0.0016*
X22	0.823625	0.559025	1.473326	0.1407	0.0704***
X24	1.325125	0.744350	1.780245	0.0750	0.0375**
Y21D	2.176922	0.665097	3.273091	0.0011	0.0006*
Y21U	0.828716	0.593773	1.395679	0.1628	0.0814***
Y22U	0.805869	0.413449	1.949137	0.0513	0.0257**
	Limit Points				
LIMIT_3:C(7)	14.97969	3.800637	3.941362	0.0001	
LIMIT_4:C(8)	18.45627	3.785610	4.875375	0.0000	
LIMIT_5:C(9)	20.36657	4.000440	5.091082	0.0000	
LIMIT_6:C(10)	29.22676	5.537793	5.277691	0.0000	
LIMIT_7:C(11)	31.20934	5.801328	5.379689	0.0000	
LIMIT_8:C(12)	37.38808	6.938657	5.388375	0.0000	
LIMIT_9:C(13)	38.30970	7.059718	5.426519	0.0000	
Pseudo R-squared	0.628354	Akaike info criterion		1.747979	
Schwarz criterion	2.231258	Log likelihood		-33.32143	
Hannan-Quinn criter.	1.933824	Restr. log likelihood		-89.65900	
LR statistic	112.6751	Avg. log likelihood		-0.628706	
Prob(LR statistic)	0.000000				

* significant at α of 0.01
** significant at α of 0.05
*** significant at α of 0.1

Model 3: final ordered probit model for operational factors

As shown in equation 6, the variables in the final ordered probit model are X31, X34, Y31D, Y31U, Y32U and Y34U. As given in table 4, Variable X34 has a z-statistic of 4.0819 and a p-value of 0.0000. It has the highest coefficient (2.2095) among the other parameters. Thus, X34 is the most significant variable at the operational level.

$$Z = 1.6577^*X31 + 2.2095^*X34 + 0.4914^*Y31D - 0.7869^*Y31U + + 0.8496^*Y32U + 0.4791^*Y34U \qquad (6)$$

TABLE 4. Estimation output of Model 3: ordered probit.

	Coefficient	Std. Error	z-Statistic	p (2-tailed)	p (1-tailed)
X31	1.657691	0.522927	3.170020	0.0015	0.0007*
X34	2.209529	0.541294	4.081937	0.0000	0.0000*
Y31D	0.491367	0.299411	1.641112	0.1008	0.0504***
Y31U	-0.786877	0.361788	-2.174966	0.0296	0.0148**
Y32U	0.849629	0.331721	2.561274	0.0104	0.0052*
Y34U	0.479136	0.354696	1.350834	0.1767	0.0884***
Limit Points					
LIMIT_3:C(7)	9.569542	2.086393	4.586644	0.0000	
LIMIT_4:C(8)	11.24779	2.045023	5.500078	0.0000	
LIMIT_5:C(9)	12.29263	2.164108	5.680230	0.0000	
LIMIT_6:C(10)	16.71073	2.792528	5.984084	0.0000	
LIMIT_7:C(11)	17.91975	2.952789	6.068753	0.0000	
LIMIT_8:C(12)	21.01933	3.410512	6.163102	0.0000	
LIMIT_9:C(13)	21.35114	3.417007	6.248490	0.0000	
Pseudo R-squared	0.607619	Akaike info criterion		1.818133	
Schwarz criterion	2.301412	Log likelihood		-35.18052	
Hannan-Quinn criter.	2.003979	Restr. log likelihood		-89.65900	
LR statistic	108.9569	Avg. log likelihood		-0.663783	
Prob(LR statistic)	0.000000				

Notes:
* significant at α of 0.01
** significant at α of 0.05
*** significant at α of 0.1

5. HYPOTHESIS TESTING

After going through a comprehensive process of model estimation and evaluation, the final models for strategic, tactical and operational levels retain the statistically significant factors in affecting the dependent variable Z. Tables 5, 6 and 7 provide a summary of these variables for the purpose of hypothesis testing.

It is important to note that one cannot directly interpret the marginal effects of the coefficients in ordered probit/ logit models. The probability of observing $Z=2$ (the lowest ranking) changes in the opposite direction of the sign of the coefficient and the probability of observing $Z=9$ (the highest ranking) changes in the same direction of the sign of the coefficient. We are able to know the signs of the changes in observing Zs in mid rankings and the marginal effects of all the coefficients only with a fair amount of calculation (Washington et al., 2003; Greene, 2008). This may be a major reason why the interpretation of coefficients was uniformly overlooked in the literature. This paper takes a step forward by unveiling the details.

TABLE 5. SUMMARY OF THE INDEPENDENT VARIABLES IN MODEL 1.

Cell	Represent	Sign of coefficient
X11	Customer service, Strategic	Individual contribution	Positive
X13	Transportation, Strategic	Individual contribution	Positive
X14	Order processing, Strategic	Individual contribution	Positive
Y14U	Order processing, Strategic	Integration with major terminal operators	Positive

TABLE 6. SUMMARY OF THE INDEPENDENT VARIABLES IN MODEL 2.

Cell	Represent	Sign of coefficient
X21	Customer service, Tactical	Individual contribution	Positive
X22	Inventory, Tactical	Individual contribution	Positive
X24	Order processing, Tactical	Individual contribution	Positive
Y21D	Customer service, Tactical	Integration with major shippers	Positive
Y21U	Customer service, Tactical	Integration with major terminal operators	Positive
Y22U	Inventory, Tactical	Integration with major terminal operators	Positive

TABLE 7. SUMMARY OF THE INDEPENDENT VARIABLES IN MODEL 3.

Cell		Represent	Sign of coefficient
X31	Customer service, Operational	Individual contribution	Positive
X34	Order processing, Operational	Individual contribution	Positive
Y31D	Customer service, Operational	Integration with major shippers	Positive
Y31U	Customer service, Operational	Integration with major terminal operators	Negative
Y32U	Inventory, Operational	Integration with major terminal operators	Positive
Y34U	Order processing, Operational	Integration with major terminal operators	Positive

Upon calculation and examination, we notice that the probabilities of observing the lower rankings of Z change in the opposite direction of the sign of the coefficient and the probabilities of observing the higher rankings of Z change in the same direction of the sign of the coefficient. For instance, when X11 increases to a higher value (e.g. from 3 to 4), the probabilities of observing the lower rankings (in this case 3, 4, 5) of Z decrease. The probabilities of observing the higher rankings (6, 7, 8) of Z increase. Regardless of the sign of the coefficient, when there is a change in an independent variable, there must be both an increase and a decrease in the probabilities of observing Zs. This is because the probabilities of observing all the rankings (2 to 9) must sum to 1. Hence, there are both positive and negative signs of the marginal effects.

As discussed previously, the ordered choices in Z represent the underlying continuous variable – value generated by a container shipping supply chain. In interpreting the marginal effects of the coefficients when we test our hypotheses, we observe the major direction of change. Let us consider X11 again. When the performance of customer service at strategic level improves, the supply chain value also increases. This is the appropriate policy implication for the stakeholders. The decrease in probabilities of observing the lower rankings of Z in statistical sense does not mean that the supply chain value reduces in practice. The decrease is simply because the probabilities of observing the higher rankings of Z increase.

Then we proceed to test hypothesis 1: higher individual contribution of

the cell activities (X_{mni}) has a positive effect on the supply chain value (Z). We check the sign of the partial slope coefficients of variables X_{mni}. Variables X11, X13, X14 in Model 1, X21, X22, X24 in Model 2 and X31 and X34 in Model 3 represent the individual contribution of the respective cell and their coefficients all have positive signs. These explanatory variables are positively related to the dependent variable Z. As explained by the ordered probit models, when the individual contribution of these cell activities enhances, it is less probable to observe the relatively low levels of supply chain value, and more probable to observe the higher levels of supply chain value. Hence, hypothesis 1 is supported. Since X11, X21 and X31 represent customer service, this reveals that customer service would be particularly important in influencing supply chain value.

To examine hypothesis 2: higher level of integration with the major shippers (Y_{mnid}) has a positive effect on the supply chain value (Z), we check the sign of the partial slope coefficients of variables Y_{mnd}. Y21D and Y31D are found to be significant. Both of them represent customer service and are positively related to Z. Similar to the above hypothesis, when Y21D and Y31D increase, it is more probable to observe higher levels of supply chain value. As a result, hypothesis 2 is supported.

Hypothesis 3 is then tested in a similar way. For Y_{mniu}, Y14U, Y21U, Y22U, Y32U and Y34U are included in the final models and they have positive coefficients. They represent inventory and order processing. It is more probable to observe higher levels of supply chain value when the level of integration with the major terminal operators in these cells increases. Variable Y31U is also included in the final model, but its coefficient has negative sign, which is different from our prior expectation. We note that the p-values of this variable are 0.0296 (2-tailed) and 0.0148 (1-tailed). There is still a slight chance of committing Type I error, rejecting the true hypothesis. Overall, hypothesis 3 is supported.

As for hypothesis 4, we examine the joint effect of the individual contribution of the cells (X_{mni}), the level of integration with the major shippers in the cells (Y_{mnid}), and the level of integration with the major terminal operators in the cells (Y_{mniu}) on the supply chain value (Z). This can be done by checking the LR statistic and its corresponding p-value of the regression models which reveal the statistical significance of the overall model. Referring back to estimation outputs which show the diagnostic statistics of the estimated models, the p-values of all the models are essentially zero. It tells that the LR statistic is highly significant. It is concluded that the joint effect of X_{mni}, Y_{mnid} and Y_{mniu} in influencing the supply chain value Z is simultaneously larger than zero. Therefore, hypothesis 4 is also supported.

6. Further Discussions and Implications

6. 1. *Implications of the Most Decisive Factors*

Similar to our prior expectation, the independent variables are linearly and positively related to Z, except for variable Y31U. As discussed previously, we cannot directly interpret the marginal effects of the coefficients in ordered response models. But the marginal effects are calculated by using the coefficients as a multiplier, as illustrated by Washington et al. (2003) and Greene (2008). Therefore, the strength of the marginal effects can be seen when we compare the coefficients among the variables.

In model 1, X11's high coefficient suggests the strength of the effect generated by this cell activity, and it is the highest amongst all the coefficients of the independent variables. Hence, at the strategic level, the individual performance of customer service is the most influential factor in affecting the value generated by a CSSC. For container shipping lines, improving customer service at the strategic level can have a significant positive effect on supply chain value. On the contrary, supply chain value will be lowered if the performance of this cell activity is worsened. The second influential factor is X13, then followed by X14 and Y14U.

The independent variables in model 2 and model 3 can be interpreted in a similar manner. In model 2, the most important factors are X21 and Y21D. Variable Y21U is also included in the model. It is interesting to note that customer service is a crucial factor at the tactical level. Improving its individual performance (X21), enhancing the integration with the major shippers (Y21D) and the integration with the major terminal operators (Y21U) in this activity can all significantly contribute to the supply chain value.

In model 3, X34 is the most decisive factor. When the individual performance of order processing at the operational level improves, supply chain value will be increased, holding other variables fixed, *vice versa*. Surprisingly, Y31U is negatively related to Z. We discuss above that there is a slight chance of rejecting the true hypothesis. Other than this reason, we note that Y21U is positively related to Z in model 2. At the tactical level, higher integration with the major terminal operators in customer service will increase the supply chain value. For policy implication, the important question is: should liners reduce the integration with the major terminal operators in customer service at the operational level to increase the supply chain value? The answer should be no. Strategic, tactical and operational levels should work in the same direction. This point was confirmed by the explanation from vari-

ous interviewees. Therefore, we also stress on the practical significance of the models, which will be discussed in the following sub-section.

Based on the statistical significance suggested by ordered probit analysis, container line operators should pay particular attention to those cell activities contained in the final models. They are the most decisive factors in determining the total supply chain value discovered by the current study and has not been highlighted by previous shipping and supply chain literature. Specifically, deployment of resources may favour these cell activities for they can generate higher impact on the supply chain value. This is far more productive than investing in other areas which have negligible contribution. According to the interviews, many respondents recognise the benefits of working more closely with their supply chain partners. Our final models may enlighten the liners by suggesting the exact areas of closer collaboration. Integration with the major shippers in terms of customer service at the tactical and operational levels is found to be important. As with the major terminal operators, inventory (tactical and operational levels), order processing (strategic and operational levels), and customer service (tactical level) should be focused on.

In terms of the areas of activities, customer service, inventory, transportation and order processing were chosen to be included in the normative model. On the whole, based on the ordered response analysis, it is apparent that customer service is the most significant area in contributing to the total value of a container shipping supply chain. It may be due to the fact that the customers of container lines are becoming more powerful. Inevitably, the liners have to address this key element of revenue source. Also, by determining customer service levels to meet what the customer desires and is willing to pay, the liners may simultaneously improve service level and reduce cost.

Another novel contribution of this paper is about the three levels of management based on the time frame involved in the normative model: strategic, tactical and operational. The strategic and tactical levels involve longer time frame and wider scope of management. Shipping lines should be particularly concerned with the crucial implications of decision making at the strategic and tactical levels for those cell activities in the final models. We find out from the analysis that more cells of Y_{mnid} and Y_{mniu} are included in the operational level than tactical and strategic levels. The integration with shippers and terminal operators becomes more important at the operational level. However, as revealed by model 1 and model 2, integration at higher levels cannot be ignored. Fostering collaboration at the tactical and strategic levels could be the step forward for bringing more benefits for CSSCs.

From the resource-based point of view, firms are able to achieve superior returns by best exploiting the internal resources and capabilities (Barney,

1999; Grant, 1999). It is advisable for the container lines to build up their core competencies by leveraging on those significant cell activities, underpinned by the resources deployed. In short, the models help the container lines by identifying the possible strategic factors in managing supply chains. Ultimately, those firms which are able to strengthen their competitive advantage in an ever-increasing competitive environment of shipping can excel in their business.

6. 2. *Implications of the Overall Model and Practical Significance*

Based on hypothesis 4, the joint effect of the individual contribution of the cell activities (X_{mni}), the level of integration with the major shippers in the cells (Y_{mnid}), and the level of integration with the major terminal operators in the cells (Y_{mniu}) on the supply chain value (Z) is simultaneously larger than zero. In other words, the overall significance of the ordered probit models is high. In this sense, the explanatory variables included are relevant and useful.

We draw three samples from the survey data set as examples. In model 1, for instance, a company has low values in the factors (x11=1.5, x13=1.5, x14=1, y14u=1.5). Hence, the supply chain value tends to be very low. The probability of observing Z=2 is 0.9598. For another company, the factors have relatively higher values (x11=3, x13=3, x14=3, y14u=4). Then supply chain value tends to be higher. The probability of observing Z=5 is 0.9593. The third company achieves very high values in the factors (x11=5, x13=5, x14=5, y14u=5). The supply chain value will also be very high. The probability of observing Z=9 is 0.9782. As a whole, X_{mni}, Y_{mnid}, and Y_{mniu} can jointly explain Z.

The final models are simpler than the postulated models in their original versions. Sixteen independent variables are retained (see tables 5 to 7 for the 16 variables) and the other twenty are dropped out of the thirty-six variables in the three models. If we adopt the terminology introduced by Gujarati (1995), the 16 statistically significant variables can be regarded as core variables and the other 20 are peripheral variables. By rigorous econometric testing, the 16 core variables are proved to have significant individual partial regression coefficients. They contribute in explaining the dependent variable Z. More exactly, Z is dependent on the 16 explanatory variables and the changes in the values of these variables will cause a change in the probability of observing a Z value. This also means that it is possible to predict the probability of observing Z in terms of the known or fixed (in repeated sampling) values of the 16 explanatory variables. In contrast, statistically, the joint influ-

ence of all the other 20 variables is small and at best non-systematic or random. Thus these peripheral variables should not be included in the regression model explicitly. Their combined effect is treated as a random variable ε. Simplicity is actually a desirable feature of a regression model. As suggested by Morrison (1983), if we can explain the behaviour of Z substantially with a few explanatory variables and it is not statistically sound to suggest other variables should be included, the model should be sufficient.

Nevertheless, it does not mean that the peripheral variables have no effect on the total supply chain value (Z). Statistically, their individual marginal contribution in explaining Z is small, so the variables should not be included separately. While it is important to draw statistical significance and implications from regression analysis, the practical significance of the variables should not be ignored (Hair et al., 2006). From the survey, it was pointed by most interviewees that all the cell activities are essential. There are by far too many aspects influencing a supply chain. Moreover, in the supply chain context, the link among the various cell activities is extremely important. It is this "link" to make it a real chain, rather than a group of separated entities. For these reasons, it would be hard to segregate the impact of each cell activity. Practically, the joint influence of all the cell activities should be the best in modelling CSSCs. This also justifies why hypothesis 4 regarding the joint effect of the explanatory variables is supported.

Furthermore, the normative model (figure 1) is useful for three comprehensive purposes, namely planning, execution, as well as monitoring and benchmarking. In this sense, it would not be sufficient to refer only to those core variables. The overall model having both the core and peripheral variables can provide a more thorough guide. Importantly, acknowledging the benefits of regression analysis, we have to understand that it is bound by certain limitations. The regression is run on the survey data obtained by interviewing 53 professionals from the top 30 container liners. The empirical findings are based on shipping lines and cannot be generalised to other members in the chain. Hence, the empirical models are most applicable to liners, while offering a reference to other parties such as shippers and port/ terminal operators. However, the conceptual model is more generic and is not restrictive to any of the chain members. As a whole, we should bear this point in mind when we make use of the empirical results, and both statistical and practical significance of the variables should be taken into account.

7. Conclusions and Suggestions for Future Research

To conclude, after a rigorous process, three ordered probit models were specified for the strategic, tactical and operational variables respectively for esti-

mating the supply chain value generated by container shipping. In general, it is found that the level of supply chain integration is positively related to the supply chain value and profit. In terms of the coefficient results, customer service activities are the most influential factor in affecting the supply chain value. Hence, we suggest firms to devote more resources and efforts in: 1) promoting supply chain collaboration; 2) upgrading customer service activities at strategic, tactical and operational levels.

The paper presents an original modelling approach and new empirical findings based on theoretic foundation in uncovering SCI in container shipping. It is a comprehensive study adding to the limited prior literature in an emerging research topic. This study opens up new horizons by providing fresh research elements in maritime transport, logistics and supply chain management. This study would be an interesting piece of work to various parties concerned with shipping and supply chain issues such as researchers, policy makers and market analysts.

The study focused on the major industry players involved, namely, shippers, container shipping lines and port/ terminal operators. Particularly, the targets of the survey were professionals from shipping lines. But container shipping supply chains involve other parties such as customs and port agents. The normative model for managing the chain is more generic and versatile and can be used to analyse the entire chain or any segment of the chain. We propose that empirical investigations can be performed on other chain members in future studies. Furthermore, we address better synchronisation of CSSCs, but the desirable format of integration, i.e. the exact collaborative arrangement, is subject to further investigation. Transaction cost theory could be a topic to be looked into. More case studies and applications, e.g. on dangerous goods and special containers can also be undertaken.

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