Investigating sea shift in international freight transport: a case between Southeast Asia and the U.S.

Tomoaki KATO
Graduate Student
International Development Engineering
Tokyo Institute of Technology
TEL/FAX +81-3-5734-3468
E-mail: katou@tp.ide.titech.ac.jp

Anthony TH CHIN
Associate Professor
Department of Economics
National University of Singapore
TEL/FAX +65-6516-3959/+65-6775-2646
E-mail: anthonychin@nus.edu.sg

Shinya HANAOKA
Associate Professor
International Development Engineering
Tokyo Institute of Technology
TEL/FAX +81-3-5734-3468
E-mail: hanaoka@ide.titech.ac.jp

Tomoya KAWASAKI
Researcher
Planning and Research Department
Japan Maritime Center
TEL/FAX +81-3-3263-9421/+81-3-3264-5565
E-mail: t-kawasaki@jpmac.or.jp

ABSTRACT

One observes a shift from air freight to maritime freight in recent years due to primarily increase in fuel costs and improvements in container and shipping technology. The area of contestability has grown larger and few commodities remain exclusively air or sea. There are few studies which look into this phenomena and this study utilizes freight data between four Southeast Asian countries to the U.S. in an attempt to study the “air-sea shift”. Stratifying the data according to sea transport ratio, transition of values and the number of commodity groups are investigated in the preliminary analysis. The result suggests that a shift of freight in favor of sea carriers is, though not obviously, observed in trade value. The binary logit model on choice between air versus sea suggest that the value per weight of commodities and shipping cost are important in addition to commodity characteristics such as unfinished products, components and finished products. The relatively low Rho square indicates the absence of other factors which this study is not able to gather.

INTRODUCTION

Maritime and air transport are major modes in transporting international freight transport. Relative to maritime freight, air freight was usually confined to high value, low weight, time sensitive, customer and destination specific due to its high costs. This is changing. Maritime transport is beginning to compete in shipping commodities such as documents, pharmaceuticals, fashion garments, electronics consumer goods, and perishable food products and etc (Coyle et al, 2010, DC Velocity Staff, 2007 and MLIT Japan Civil Aviation Bureau, 2009). As part of combating climate change, DELL is progressively using sea transportation in shipping computer equipment (Green Transportation and Logistics, DELL). In recent years, pharmaceutical products such as Ventolin and blood products are shipped as chilled or frozen (UK P&I CLUB, 2002). This modal shift of international freight is referred to as “sea shift”. Worldwide growth in ocean import tonnage has grown faster than air import tonnage since 2004. In Asia, this trend has been observed since 2003. A survey concluded that 16 out of 21 shippers in Japan had shifted shipments from air to sea (MLIT Japan Civil Aviation Bureau, 2009) The major drivers of sea shift are: (i) the rise in air freight rates; (ii) enhanced and efficient sea transport service; (iii) changes in global supply chain and logistics; and (iv) desire for environmentally friendly transportation. Thus the demarcation between commodities ‘captured’ by sea and air begin to blur creating a large area of contestability. Few studies have addressed this phenomenon as this shift unfolds. Against this backdrop, this study attempts to understand the ‘sea shift’ phenomenon, more specifically, to discover to what extent ‘sea shift’ is true and to ascertain the factors which affect mode choice. The analysis utilizes freight transport data between the U.S. and four major Southeast Asian countries drawn from TradeView™, by Zepol (http://www.zepol.com/).

LITERATURE REVIEW

Remarkably fewer studies have been done on freight mode choice than on passenger travel mode choice mainly due to data availability issue. Studies on freight mode choice models originally began in 1970s. At that time logistics operations started to become increasingly complex and gather more attention among researchers. From 1980s onwards, modeling based on random utility theory began to prevail in the field of discrete choice modeling and logit model became mainstream in freight/passenger mode choice modeling, although some studies which do not adopt logit model are found such as Abdelwahab (1998) and Tsuboi et al (2010). Logit model has been widely applied and used due to its theoretical consistency and superiority in accuracy and handling. Picard and Gaudry (1998) studied the superiority of a Box-Cox logit model over the linear one using the example of freight mode choice between truck and rail in Canada. Another good example of developed logit mode used for freight mode choice is nested logit model (Jiang et al, 1999). Weighted logit freight mode-choice model attempted by Rich et al (2009) is also derived from the nested logit model.

When it comes to the modes examined in previous studies, rail, truck and their combination often appear (Nam, 1997; Abdelwahab, 1998; Jiang et al, 1999 and Norojono et al, 2003). There have been not so many studies done which includes maritime transport in its choice set (Rich et al, 2009 and Hayakawa et al, 2011) partly because data for shipping industry is relatively inaccessible. As far as we know, Tsuboi et al (2010) is the only research which deals with mode choice between sea and air. It focuses on increasing competition between sea and air transport and considers a mode choice model taking into account time, cost, inventory cost and obsolescence cost. But other than Tsuboi et al (2010), no attempt has been made with a focus on air-sea mode choice and influential attributes regardless of overall sea shift trend and popularization of logit freight mode choice modeling.

METHODOLOGY

This study consists of two major analytical parts. As stated in the introduction, it is said that the trend of sea shift has been globally progressing since the mid-2000s. Firstly, an attempt was made to reveal whether the sea shift trend is true of freight transport between the U.S. and Southeast Asia by investigating container traffic statistics for certain commodity groups (10 digits HTS code) between four selected ASEAN countries (Malaysia, Thailand, Singapore and Indonesia) and all the U.S. districts. More specifically sea transport ratio, which represents how many percent in value was shipped by sea and is hereafter written as STR in tables and figures, was calculated as an indicator of sea shift. Dividing data into five categories: air dependent (STR 0 to 10%), slightly air dependent (STR 10 to 40%), high modal competition (STR 40 to 60%), slightly sea dependent (STR 60 to 90%), sea dependent (STR 90 to 100%), an exploration on the transition of the number and the value of commodities was done. The data of commodities with less than 100,000 USD value were eliminated beforehand in order to avoid the effect of minor commodities.

An analysis was done to clarify causes and attributes determining mode choice. Modal choice problems were set as simple binary choice problem between sea and air. Logit model was employed as modeling methodology; due to its wide acceptance in the field of modal choice modeling and ease in handling. Under random utility theory, the probability for n to choose alternative i is written as follows (Ben-Akiva and Lerman, 1985)

$$
\begin{aligned}
P_n(i) &= \Pr\left(U_{in} \geq U_{jn}\right) \\
&= \Pr\left(V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn}\right) \\
&= \Pr\left(\varepsilon_{jn} - \varepsilon_{in} \leq V_{in} - V_{jn}\right) \qquad (1)
\end{aligned}
$$

Here

U_{in}: Random variables representing utility for n choosing alternative i.

V_{in}: Systematic components of U_{in}

ε_{in}: Disturbance components of U_{in}

In logit model, $\varepsilon_n = \varepsilon_{jn} - \varepsilon_{in}$ is assumed to be logistically distributed. Hence the probability is written as follows.

$$
P_n(i) = \exp(V_i) \Big/ \sum_{k=1}^{N} \exp(V_k) \qquad (2)
$$

Many models were estimated with changing variables in order to discover critical variables. Their utility function will be shown in the following section along with their estimation results. Unlike the preliminary analysis, destinations were confined to two districts: Los Angeles and New York. Eliminating commodities having less than 100,000 USD value similarly in the preliminary analysis, we used the year 2011 data for estimating parameters of utility function. Out of the data gathered, 10 to 40% STR commodities and 60 to 90% STR commodities were used as choice sets. The former commodities were seen as alternative 0: by air, and the latter as alternative 1:by sea. In other words, one HTS 10 digits commodity acts as one sample, even though it is, in fact, accumulated data for a year and does not correspond to one single mode choice. As for software for estimation, BIOGEME (Bierlaire, 2003) was used.

DATA

TradeView^{TM}, which is provided by Zepol, was used for data source in the present study. TradeView^{TM} is based on “trade data released by the U.S. Census Bureau’s Foreign Trade Division” (TradeView^{TM} Website, Zepol). In this database, various items, such as air/vessel value and air/vessel weight, are provided for each commodity groups. At the most precise level, HTS code 10 digits data can be obtained at the level of the U.S. districts although it does not mention districts or ports for the other country.

Two different types of datasets were examined for different purposes in the present study. The U.S. imports data from four selected ASEAN countries to all the U.S. districts were used for the preliminary analysis whereas data of logit modeling has only two districts as destination.

Names of items	*Definitions*
Value	Value of general imports assessed by U.C. customs, or the price actually paid or payable, excluding U.S. import duties, freight, insurance and other charges.
Vessel/Air Value	Value of goods (in dollars) transported by waterborne vessels/airborne carriers.
Vessel/Air Weight	Weight of goods (in kilograms) transported by waterborne/airborne carriers.
Consumption Import Charges	Total cost of all freight, insurance and other charges (excluding U.S. import duties) incurred in bringing the merchandise from the carriers at the foreign port to the carrier at the first port of entry in the U.S.
Air Import Charges	Total cost of all freight, insurance and other charges (excluding U.S. import duties) incurred in transporting the merchandise via air from the carriers at the foreign port to the carrier at the first port of entry in the U.S.

Table 1. Definitions of collected data

Source: **Zepol TradeView^{TM} Glossary**

As for commodity types, fresh and processed foods (start with 02, 03, 04, 05, 06, 07, 08, 09 and 10 in HTS codes), pharmaceutical and organic chemicals (starts with 29 and 30), clothing (starts with 61 and 62) and manufacturing goods (starts with 84, 85 and 90) were chosen for both datasets because they are generally perceived as commodities in area of contestability according to some reports. The data dating back to 2007 is available and annual data from 2007 to 2011 was collected and analyzed; even though monthly data is also available. The items we referred to and their definitions are shown in Table 1.

RESULTS OF ANALYSIS

The result of preliminary analysis is summarized in Table 2. First of all it should be noted that the total trade value shows sudden drop in 2009. Similar trend can also be seen in STR 60 to 90%. It is thought to be due to worldwide financial crisis triggered by Lehman’s fall. Possible explanation is that the demand in the U.S. dramatically dropped in the financial crisis and gradually picked up in following years. Turning to other groups, we can see that sea dependent commodities (STR 90 to 100%) and commodities in high competition zone (STR 40 to 60%) have been increasing at slower pace. On the other hand STR 0 to 10% shows consistent decreasing trend. Thus, it suggests that dependence on sea transport has been increasing. In other words, ‘sea shift’ seems to be taking place in terms of traded value. When it comes to the number of commodity groups in each stratum, it is hard to see any consistent increasing or decreasing trend. It is enough to mention that similar trend can be observed in the total, STR 0 to 10% and STR 60 to 90%. STR 10 to 40% and 40 to 60% show gradual rise after 2009. But these results cannot be sufficient evidence of ‘sea shift’. From the aforementioned results, we can reach the tentative conclusion that ‘sea shift’ is progressing in value, but not in commodity variety. The authors speculate that this ‘sea shift’ results from the improvement of service quality in sea transport.

Table 3 shows that manufacturing goods (HTS 84 and 85) are predominant in terms of both quantity and varieties. There is no clear consistent trend seen in commodity group breakdown other than that STR 10 to 60% commodities have been slightly increasing in manufacturing goods.

As for the modal choice modeling, the estimation results of three different models, out of a number of models tried, are presented and discussed for comparison. The utility functions and the estimation results for respective model are shown in table 4 and 5. The logarithm of value per weight was incorporated into the models because it showed better fits than without logarithm. It is consistent with a result of previous study (Rich et al, 2009). The observation number is 669 which is not identical to sum of STR 10 to 40% and 60 to 90%. This is because all the datasets had to have more than 100,000 USD in single OD pairs. Consequently the commodities used in logit models were mostly from HTS 61, HTS 62, HTS 84, HTS 85 and HTS 90.

		Year 2007	*Year 2008*	*Year 2009*	*Year 2010*	*Year 2011*
Value [Million USD] (Brackets) show share (%)	Total	63,988	59,743	50,647	55,652	57,544
	STR 0 to 10 %	39,528	32,966	27,881	31,074	29,801
		(61.77)	(55.18)	(55.05)	(55.84)	(51.79)
	STR 10 to 40 %	4,978	5,167	3,548	4,260	4.695
		(7.78)	(8.65)	(7.00)	(7.65)	(8.16)
	STR 40 to 60 %	1,018	1,785	2,536	2,412	4,191
		(1.59)	(2.99)	(5.01)	(4.33)	(7.28)
	STR 60 to 90 %	8,063	8,962	4,755	6,332	6,595
		(12.60)	(15.00)	(9.39)	(11.38)	(11.46)
	STR 90 to 100%	10,401	10,862	11,927	11,573	12,262
		(16.25)	(18.18)	(23.55)	(20.80)	(21.31)
# of commodity groups	Total	2,079	2,076	1,966	2,017	2,077
	STR 0 to 10 %	432	423	404	459	426
	STR 10 to 40 %	216	209	215	230	241
	STR 40 to 60 %	124	122	118	133	148
	STR 60 to 90 %	436	423	390	414	446
	STR 90 to 100 %	871	899	839	781	816

Table 2. Value and the number of commodity groups in stratified categories

			Year 2007	*Year 2008*	*Year 2009*	*Year 2010*	*Year 2011*
Foods	Total		170	185	181	180	184
	STR	0 to 10%	14	18	17	14	15
	STR	10 to 40%	5	4	2	5	4
	STR	40 to 60%	3	2	5	2	2
	STR	60 to 90%	11	8	4	7	12
	STR	90 to 100%	137	153	153	152	151
Chemical and Pharmaceutical	Total		93	93	91	106	110
	STR	0 to 10%	25	24	22	27	31
	STR	10 to 40%	3	5	3	1	3
	STR	40 to 60%	4	4	3	5	4
	STR	60 to 90%	5	3	3	3	7
	STR	90 to 100%	56	57	60	70	65
Clothing	Total		543	523	488	484	512
	STR	0 to 10%	9	7	6	7	7
	STR	10 to 40%	26	15	14	18	15
	STR	40 to 60%	25	22	17	22	27
	STR	60 to 90%	207	176	150	189	195
	STR	90 to 100%	276	303	301	248	268
Manufacturing Goods	Total		1,273	1,275	1,207	1,247	1,271
	STR	0 to 10%	384	374	359	411	373
	STR	10 to 40%	182	185	196	206	219
	STR	40 to 60%	92	94	93	104	115
	STR	60 to 90%	213	236	233	215	232
	STR	90 to 100%	402	386	326	311	332

Table 3. The number of commodity groups in stratified categories by commodity types

	Utility function
Model 1	$V^{air} = \beta_{CPW^{Air}} * CPW^{Air} + ASC$ .... (same throughout three models) $V^{sea} = \beta_{CPW^{Sea}} * CPW^{Sea} + \beta_{VPW} * Log(VPW^{Total})$
Model 2	$V^{sea} = \beta_{CPW^{Sea}} * CPW^{Sea} + \beta_{VPW} * Log(VPW^{Total}) + \beta_{HTS61dummy} * HTS61dummy + \beta_{HTS62dummy} * HTS62dummy + \beta_{HTS84dummy} * HTS84dummy + \beta_{HTS90dummy} * HTS90dummy$
Model 3	$V^{sea} = \beta_{CPW^{Sea}} * CPW^{Sea} + \beta_{VPW} * Log(VPW^{Total}) + \beta_{Ddummy} * Ddummy + \beta_{Partsdummy} * Partsdummy$

ASC: Alternative specific constant, *CPW*: Cost per weight (Air/Vessel import charges divided by air/vessel weight), *VPW*: Value per weight (Air/Vessel value divided by air/vessel weight), *HTS61/62/84/90dummy*: a dummy variable which takes value 1 if the commodity's HTS code starts with 61/62/84/90. *Ddummy*: a dummy variable which takes value 1 if its destination is New York, *Partsdummy*: a dummy variable which takes 1 if the commodity is not finished product but parts.

Table 4. Utility functions of the estimated models

	Model 1	*Model 2*	*Model 3*
# of observations	669	669	669
ASC	-5.17	-4.63	-6.42
	(***-11.10)	(***-8.10)	(***-11.33)
$\beta_{CPW^{Air}}$	-0.0175	-0.0196	-0.0279
	(-0.89)	(-0.99)	(-1.21)
$\beta_{CPW^{Sea}}$	-0.295	-0.285	-0.208
	(**-2.56)	(**-2.42)	(*-1.88)
β_{VPW}	-1.11	-0.999	-1.31
	(***-9.02)	(***-7.36)	(***-9.49)
$\beta_{HTS61dummy}$		0.353	
		(1.06)	
$\beta_{HTS62dummy}$		0.407	
		(1.54)	
$\beta_{HTS84dummy}$		-0.164	
		(-0.61)	
$\beta_{HTS90dummy}$		-0.358	
		(-1.00)	
β_{Ddummy}			-0.943
			(***-4.48)
$\beta_{Partsdummy}$			-0.931
			(***-3.50)
# of parameters	4	8	6
Likelihood Ratio Test	234.879	241.657	265.512
Adjusted Rho square	0.245	0.243	0.273

* 10 % significant, ** 5% significant, *** 1% significant

Table 5. Results of estimation, (Brackets) show t-value

In model 1, only four parameters were estimated and among them only one coefficient, $\beta_{CPW^{Air}}$, is not statistically significant. Although three variables are significant at 5% and the model itself is 1% significant in likelihood ratio test, adjusted rho square is only 0.243 which is not high compared to other studies using logit model (for example, Rho square is approximately 0.5 in Nam (1997) and approximately 0.4 in Hayakawa et al (2011)). $\beta_{CPW^{Air}}$ is unalterably insignificant in every specification. That is possibly because air transport commodities normally have high added value or/and time-sensitivity and shipping rate does not have remarkable influence. The signs of significant parameters are consistent with the expectation. They can be interpreted that high sea transport cost and high value for unit weight decrease the utility of sea transport - i.e. those commodities are more likely to be shipped via air. On the other hand, ASC, which is in the function for air, shows negative sign and large value of coefficient. It implies that there are some important backgrounds which are not taken into account in the model and act to put down the utility of air transport. Alternatively we can also interpret it as meaning that many of shippers select sea transport, just following custom and without any consideration. In one model tried, which is not presented in table 5 and had seven ODdummy variables standing for eight OD pairs, five out of seven dummy variables was 5% significant. Ideally OD pairs should have been more specifically identified and actual transit time should have been used as variables for more accurate estimation. In model 2, four of HTSdummy variables were added to represent commodity characteristics. But none of them passes 5% significant criteria possibly because categorization by two digits HTS code is too crude to represent their properties. Those trial and errors led to find model 3 where two of dummy variables are incorporated: Partsdummy and Ddummy. Considering their signs, it can be said that shipment to LA and finished products tend to be shipped by sea transport. As for destinations, it makes sense in that LA is geographically closer to Southeast Asia and air transport accordingly cannot show its speed advantage. On the other hand, it was unexpected that finished product more tend to be shipped by sea because it is viewed finished product had higher added value and deserved air transport. This may be explained by the fact that parts commodities tend to require high punctuality and swiftness.

CONCLUSION

This study examined the sea shift from air transport and ascertains factors that influence the mode choice in selected commodities between four Southeast Asian countries and the U.S. Preliminary results partly confirmed this trend. Sea shift, however, does not seem to be taking place in terms of commodity variety. Possible explanation is that Southeast Asia and the U.S. are not geographically as close as drivers of sea shift exceed the superiority of air transport in speed. The results of the binary logit modeling indicate that variables representing commodity characteristic, route and cost significantly affect mode choice except for air transport cost whose coefficient are extremely small. The relatively low explanatory power of the models may be due to omission of important variables.

One limitation of the present study is that each observation in the logit modeling is aggregated data and does not reflect mode choice of a single shipment. Further, route attributes were represented by dummy variables due to unavailability of route specific data. Accurate route attributes should give better results. The inclusion of more origin and destination covering lager and longer distances areas such as Europe, Middle East and East Asia could bring forth the advantage of speed over cost. A more precise classification on commodity characteristics, which was not achieved in this study due to data availability, is also encouraged to be attempted.

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