

AN EMPIRICAL EXAMINATION OF TRANSPORT MODAL SELECTION IN GLOBAL SUPPLY CHAINS

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ABSTRACT

This study examines the factors that impact the decision of transport modal choice in global supply chains. The factors affecting modal decision include: industry characteristics, modal characteristics, shipment characteristics and regional characteristics. This study proposes that the decision maker of the modal choice aims to maximize its own profit and considers revenue and cost drivers when making the modal decision. The results show that the manufacturing industries use more air shipping for both exports and imports when faced with a positive sales surprise and high demand variation. The results also indicate that more concentrated industries will use less air transport for both imports and exports. Modal decisions for exports are also impacted by the cost of capital and the gross margin ratio.

Key Words: Transport Modal Selection, Global Supply Chain

INTRODUCTION

Air shipping is the more expensive transport option in global supply chains compared with ocean shipping. Despite the higher unit transport cost, air shipping in international trade has been rising significantly in the past four decades. Why have firms increased their use of air shipping in global supply chains despite its higher costs? Transport modal selection should be examined from a supply chain perspective. Global transportation links the operations of shippers and consignees in two countries and the selection of a transport mode will inevitably have a direct impact on the operational performance of the decision maker and its counterparts. The decision on transport mode should be based on the maximization of the decision maker's profit not just the shipping costs and commodity type. That is, it is crucial to take into account the revenue and cost drivers that compose the decision maker's profit in the modal decision.

This study addresses three research questions: (1) What are the revenue and cost drivers contributing to the transport modal decision in the global supply chain? (2) To what extent do these drivers affect the modal decision? (3) Do these drivers have a distinct impact on the modal decision for imports and exports? Using the trade data between the U.S. and 12 Asian trade partners at the industry level and the annual survey data of the U.S. manufacturers aggregated at the industry level, this study examines the factors that affect the transport modal selection in global supply chains.

LITERATURE REVIEW

Traditionally, freight transportation demand (FTD) studies are classified into two categories: aggregate models and disaggregate models. Aggregate studies use the data of the market shares of different modes and the characteristics of different modes, the shipment, and the region to estimate the decision of modal choice. Because of the lack of waybill information, researchers have to aggregate the information at either the commodity level and/or the regional level and examine the impact of the aggregated variables on the modal choice. The common modal characteristics used in previous studies include the differences in rates and transit time, the variations of transit time, and the average shipment size (Oum, 1979; Friedlaender & Spady, 1980; Hummels & Schaur, 2012). The shipment characteristics used in previous studies include the value per weight, the density, the price volatility, the inventory costs of the commodity, and the relevance to timeliness (Friedlaender & Spady, 1980; Hummels & Schaur, 2010; Hummels & Schaur, 2012). Disaggregate studies use the data from a survey of shippers or shipments to predict shippers' mode choice by including the characteristics of individual shipments or shippers. Because the data used in disaggregate studies contain richer information about shipments, shippers, and receivers, it enables researchers to conduct deeper analyses about the behaviors of firms and individuals.

Generally, disaggregate mode choice models are considered more precise than aggregate models (Winston, 1981). However, because disaggregate models require a huge amount of data, which are usually confidential, for all modes, Winston (1983) indicates that aggregate models might be more useful for studies at a regional or national level. This study uses aggregate models to estimate the model of manufacturing firms' modal choice between air and sea due to the

challenge of accessing information on individual shipments for international trade. Aggregate models allow a researcher to conduct a study with aggregate trade data.

THEORY AND HYPOTHESES DEVELOPMENT

Neoclassical economic theory indicates that the objective of a firm is to maximize its profit π , which is equal to the difference between total revenue (TR) and total cost (TC):

$$\pi = TR - TC. \quad (1)$$

The calculation of total revenue, the product of the selling price (P) and the quantity sold (Q), is straightforward. The higher price and the more quantity sold (or fewer lost sales), the more revenue earned by a firm. The population, the selling price, the price of substitutes, and the availability of the product determine the quantity sold.

$$TR = PQ, \quad (2)$$

$$Q = f(\text{Population, Price, Price of Substitute, Availability}). \quad (3)$$

The determination of total cost is more complex. Output (Y) is a function of inputs including capital (K), labor (L), materials (M), air transport (A), ocean transport (O), technology (t), and the quality of the inputs (\bar{X}). Total cost is a function of output (Y), input prices such as the costs of capital (R^K), labor (R^L), material (R^M), and shipping rates of air (R^A) and ocean (R^O), and technology (t). The functions of output and total cost are as follows:

$$Y = g(K, L, M, A, O, t, \bar{X}), \quad (4)$$

$$TC = h(Y, R^K, R^L, R^M, R^A, R^O, t). \quad (5)$$

Supply chain members have separate revenue functions and cost functions and aim to maximize their own profits, which are the difference between their revenues and their costs. Transportation links the operational activities between supply chain members.

This study proposes that a firm adopts different transport modes based on the nature of demand. When a firm is planning its demand and transport policy for next year, the historical trend of sales is an important baseline. Demand below trend is relatively predictable and certain. A firm could build up inventories based on the predicted sales in advance and use ocean shipping with its longer transit time and lower transportation costs. If the market demand surges above expectation, a firm may use faster transportation such as air shipping to fulfill the unexpected orders in order to minimize the sales loss and customer churns. As demonstrated in Equations 2 and 3, revenue is determined by the quantity sold, while the quantity sold depends on product availability. To increase revenue, a firm may increase the product availability by using faster transportation to replenish inventory when demand is higher than expected. At the industry level, if the aggregate sales of an industry increase beyond its historical trend, implying a positive sales surprise—measured by the percentage of demand over the historical trend—, this industry may use more air shipping than other industries. Hypothesis 1 is therefore:

H1: The share of air transport in trade for an industry is positively associated with its positive sales surprise.

Demand variation may affect the costs of firms and have an impact on their modal decisions. High demand variation may imply that a large portion of demand is uncertain. Inventory theory indicates that safety stock is a function of the service level, the length of lead times, the size of demand, and the variation in lead time and demand. High demand variation leads to more safety stock at the same service level. Evers (1999) finds that as the coefficient of variation in demand increases, the option of shorter lead times becomes more attractive. Using faster transportation like air shipping shortens the replenishment lead time so that the demand variation during lead time is lower, and hence a firm can keep a lower inventory level at the same service level. At the industry level, an industry with high demand variation—measured by the coefficient of variation in monthly shipment value within one year—, may have a higher percentage of air shipping in trade than other industries. Hypothesis 2 is therefore:

H2: The share of air transport in trade for an industry is positively associated with its demand variation.

The gross margin ratio could affect the transport modal decision. In inventory theory, the gross margin ratio is a measure of underage cost, and a high gross margin ratio implies higher sales losses or opportunity costs caused by unmet demand. A commodity with a high gross margin ratio offers firms an incentive to realize demand through faster transportation. Additionally, the cost of air shipping accounts for a smaller portion of profit for high gross-margin products, making air shipping more affordable. At the industry level, an industry with a high gross margin ratio could have a higher percentage of air shipping than other industries. Hypothesis 3 is therefore:

H3: The share of air transport in trade for an industry is positively associated with its gross margin ratio.

The cost of capital could affect the choice of transport mode. To acquire the capital needed for investment, a firm may borrow money from banks, issue bonds, or raise funds from stockholders. The interest paid to banks and bondholders and the dividends paid to stockholders are considered the cost of capital. Firms with a high cost of capital are under greater pressure if large amounts of working capital are required for their operations. The requirement for working capital is measured by the cash-to-cash cycle, which is calculated as inventory days plus account receivable days minus account payable days. The longer the cash-to-cash cycle, the more cash is tied up in a firm's working capital. If a firm has a high cost of capital, it implies that a firm could be eager to shorten the cash-to-cash cycle so as to reduce its working capital. As a result the total cost of capital would also be reduced. Because ocean shipping, which features large shipment sizes and long transit times, results in more in-transit inventories compared with air shipping, the switch from ocean to air shipping will reduce the inventory days, the working capital, and the total cost of capital. At the industry level, an industry with higher cost of capital may have an incentive to increase their air shipping share. Hypothesis 4 is therefore:

H4: The share of air transport in trade for an industry is positively associated with its cost of capital.

The intensity of competition may have an impact on modal selection. Traditional S-C-P (Structure-Conduct-Performance) theory indicates that market structure determines a firm's conduct, which leads to a firm's performance. Firms may have relatively high bargaining power over their customers in monopoly or oligopoly markets that consist of one or a few players.

Hence, the firm may be able to either negotiate a more favorable contract or promise a later delivery date. That is, responding to unmet demand, firms in a monopoly or oligopoly market are under less pressure to use the faster and more expansive transport mode. At the industry level, an industry with high concentration ratio measured by the market share of top four firms (CR4) may have a lower air share in trade compared with that with a low concentration ratio. Hypothesis 5 is therefore:

H5: The share of air transport in trade for an industry is negatively associated with its concentration ratio.

DATA AND METHODOLOGY

To test these hypotheses, this study reviews the literature and classifies the factors affecting the decision of transport mode into four categories: industry characteristics, modal characteristics, shipment characteristics and regional characteristics. For the industry characteristics, this study has identified revenue and cost drivers including positive sales surprise (PSURPRISE), demand variation (CVD), gross margin ratio (GM), cost of capital (WACC), and concentration ratio (CR). For characteristics of the transport mode, the ratio of air-to-ocean shipping rates (AO_RATIO) at the country and industry level and the absolute value of difference in air-to-ocean transit time (TT_DIFF) at the country level are included in the estimation model. For shipment characteristics, this study includes the value-to-weight ratio (VW_RATIO). For the characteristics of region, regional dummies are used to control for the differences of each region.

To investigate the modal choice decision in global supply chains, this study utilizes trade data from U.S. exporters/importers published by the U.S. Census Bureau during 2002-2009. This database provides rich information about the import and export trade including value, weight, import shipping charges, transport mode, and origin/destination country on a monthly basis. The trade data related to the U.S. manufacturers is the focus of this study. In addition, this study focuses on the trade between the U.S. and 12 trade partners in Asia including China, Hong Kong, India, Indonesia, Japan, South Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, and Vietnam, which are the U.S. top 12 trade partners in Asia and account for 88% of Asian GDP in 2010 (Census Bureau, 2012). The industry characteristics like positive sales surprise, demand variation, and gross margin ratio are calculated from the Annual Survey of Manufacturers and the Manufacturers' Shipments, Inventories, and Orders (M3) survey prepared by the U.S. Census Bureau, and the cost of capital at the industry level is collected from Morningstar.com.

We estimate multilevel mixed-effects linear regression models, which consider both fixed effects and random effects as well as robust standard errors. While the fixed effects are tested for the explanatory variables and control variables, the random effects take the form of random intercepts at the country level, the industry level, and the year level.

RESULTS AND DISCUSSION

Table 1 presents regression results for imports and exports, separately. Positive sales surprise and demand variation are both significant factors contributing to the use of more air shipping for both imports and exports, underscoring the importance of uncertain demand in transport modal selection. The results support the hypotheses that firms in this industry may use a faster transport

mode to realize demand when either the actual demand of an industry exceeds the trend or the demand has high fluctuations. The gross margin ratio and cost of capital are found to have a significant impact on transport mode for exports only. In addition, this study substantiates the traditional S-C-P theory by showing that the market structure will affect firms' conduct in terms of modal choice. Even facing more demand than historical trend, the proportion of air shipping in a high-concentration industry does not increase accordingly. Instead, firms may use their bargaining power to negotiate a later delivery time. Because there are fewer competitors in the market, the risk of customer churn and sales loss are lower than that in a low-concentration market.

Table 1 Summary of Estimation Results

CATEGORY	VARIABLE	U.S. IMPORTS			U.S. EXPORTS		
		Coef.	Sig.	Hypothesis [#]	Coef.	Sig.	Hypothesis [#]
INDUSTRY	PSURPRISE	0.0383	**	H1 S	0.1343	***	H1 S
	CVD	0.2301	**	H2 S	0.3654	***	H2 S
	GM	-0.0350		H3 NS	0.2544	***	H3 S
	WACC	-0.0531		H4 NS	0.4475	***	H4 S
	CR	-0.0427	*	H5 S	-0.2979	***	H5 S
MODE	TT_DIFF	-0.0172			0.0650		
	AO_RATIO	-0.3339	***		-0.7178	***	
SHIPMENT	VW_RATIO	0.0038	***		0.0014	***	

#S represents that the hypothesis is supported; NS represents that the hypothesis is not supported.

*** p<0.01, ** p<0.05, * p<0.1

CONCLUSIONS

This study examines the factors that impact the decision of transport modal choice in global supply chains. The factors affecting modal decision include: industry characteristics, modal characteristics, shipment characteristics and regional characteristics. This study proposes that the decision maker of the modal choice aims to maximize its own profit and considers revenue and cost drivers when making the modal decision. The results show that the manufacturing industries use more air shipping for both exports and imports when faced with a positive sales surprise and high demand variation. The results also indicate that more concentrated industries will use less air transport for both imports and exports. Modal decisions for exports are also impacted by the cost of capital and the gross margin ratio.

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