ABSTRACT

Title of dissertation: Transport Modal Selection and Inventory Levels in the Context of Global Supply Chains

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In this dissertation, I study the transport modal selection in global supply chains and its effects on operational performance. First, I examine the factors that affect the transport modal selection and propose that revenue drivers and cost drivers of decision makers determine their transport modal selection in pursuit of profit maximization. Then, I study the effects of the use of air shipping in export on shippers' operational performance in terms of inventory levels.

In the first essay, this study examines the macro and micro factors that affect the decision of transport modal choice in global supply chains. The factors affecting modal decision are classified as the characteristics of industry, mode, shipment, and region. This study proposes that the decision maker of the modal choice aims to maximize its own profit, taking the revenue drivers and cost drivers into account. The results show that both importers and exporters use more air shipping for high-value products and when there is a positive sales surprise. Large importers and exporters have a smaller proportion of air shipping compared with small ones. While an importer's modal decision is highly

associated with demand dynamics, an exporter's decision is more determined by gross margin and cost of capital but less by demand variation.

In the second essay, this study examines the effects of air share on manufacturing inventories. As globalization expands a firm's geographic coverage of business, the literature indicates that globalization has led to higher inventory levels due to longer supply chains. The experience in the U.S. domestic market showing that air transport plays a more important role in the practice of JIT after the deregulation in 1978 could be applicable to global markets. This study finds that the usage of air shipping in export can effectively reduce manufacturers' inventory levels at a diminishing rate. In addition, transportation modal selection is associated with profit maximization. It is found that the demand variation contributes to more use of air shipping. In addition, higher gross margins, cost of capital, and the relevance to timeliness facilitate firms to use air shipping to capture the demand and shorten the cash cycle. Furthermore, the industries with larger major players have higher shares of ocean shipping because of risk pooling advantage. For practioners, the results are used to develop guidelines for transport modal decision including the breakeven point of carrying costs based on total cost minimization and optimal air shares based on profit maximization. This study reiterates that a firm should pursue profit maximization rather than total cost minimization only.

TRANSPORT MODAL SELECTION AND INVENTORY LEVELS IN THE CONTEXT OF GLOBAL SUPPLY CHAINS

By

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Dissertation submitted to the Faculty of the Graduate School of the
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Dedication

This dissertation is dedicated to my wife, Yifen, who sacrificed her career and spent all her time and efforts supporting me and taking care of family. Also, to my lovely daughters, Dora and Sophie, who are the angels in my life and provide motivation for me to complete the doctoral program in four years. To my parents, who provided me with good education, love, and all kinds of supports to my career and my life.

I dedicate this dissertation to God the Father and Jesus, the Son of God.

Your word is a lamp for my feet, a light on my path.

~ Psalm 119:105

I can do all this through Him who gives me strength.

~ Philippians 4:13

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Chapter 1 Introduction

1.1 Introduction

Since the Wright Brothers kicked off their first manned flight in 1903 in North Carolina, air transport has offered a faster but more costly solution, compared with sea and ground transport, for people to travel and ship goods between distant points in the world. The importance of air transport in international trade has been rising significantly in the past four decades (see Table 1-1). During 1975-2004, the volume of worldwide air cargo shipments has been growing at a 7.4 percent annualized rate, compared with ocean's 4.5 percent. From 1965 to 2004, the air share of U.S imports increased 23.4 percentage points. As of 2004, air shipments of U.S. exports have increased by 40.9 percentage points and account for over half of all export value excluding Canada and Mexico (Hummels, 2007).

Table 1-1 The Statistics of World Trade and U.S. Air Trade*

	World Trade				U.S.: Air Share of Trade Value	
	Quantity of nonbulk cargoes					
	Million tons		Billion ton-miles			
Year	Ocean	Air	Ocean	Air	Imports	Exports
1951				0.2		
1955				0.3		
1960	307			0.7		
1965	434		1537	1.8	8.1	11.9
1970	717		2118	4.3	12.1	19.5
1975	793	3.0	2810	7.7	12.0	19.3
1980	1037	4.8	3720	13.9	13.9	27.6
1985	1066	6.5	3750	19.8	19.8	36.3
1990	1285	9.6	4440	31.7	24.6	42.3
1995	1520	14.0	5395	47.8	33.1	44.3
2000	2533	20.7	6790	69.2	36.0	57.6
2004	2855	23.4	8335	79.2	31.5	52.8
Annualized growth rates 1975–2004	4.52	7.37	3.82	8.35	3.40	3.53

Source: Hummels (2007)

*excluding Canada and Mexico

The growth in the air transport sector could be explained from both macro and micro perspectives. From a macro perspective, the liberalized air service agreements (ASAs) may have contributed to the growth of air transport in the world trade. Before the late 1970's, the majority of ASAs regulated international air transport in a restrictive manner. As globalization becomes a trend in the world, stronger demand for international travel and goods flow has resulted in more liberalized ASAs. Based on an estimate of the ICAO secretariat (2009), about 31 percent of country-pair routes with non-stop scheduled service in the world were conducted under either regional liberalized or bilateral open skies ASAs in 2008, compared with 7 percent in 1998. The literature indicates that liberalized ASAs lead to more competition, lower prices, and thus higher traffic growth (Dresner and Windle, 1992; Maillebiau and Hansen, 1995; Marlin, 1995; Melville, 1998; Robyn et al., 2002; InterVISTAS, 2006; Fu et al., 2010). These changes may have led to more usage of air shipping in trade.

From a micro perspective, some studies argue that the growth in the air transport sector is driven by three reasons: the cost decline of air freight due to technological change (Hummels, 2009), the increasing share of the ICT (information and communication technology) products which have higher value and lighter weight (Hummels, 2009), and globalization which increases the demand for faster and more reliable cargo movements across regions (Su et al., 2011). It implies that firms' transport modal decision is associated with shipping cost, product value, and firms' operational strategy.

As globalization is becoming increasingly important in firms' operational and marketing strategies over the past decades, it requires more studies on transport modal selection in global supply chains. Because global transportation links the operations between shippers and consignees in two countries, the selection of transport mode will inevitably have a direct impact on the operational performance of the decision maker and its counterpart. Given that firms pursue the maximization of profit, how do firms make transport modal decisions in global supply chains? How do firms' transport modal decisions affect their operational performance? This study aims to answer the research questions above.

1.2 Background: The Development of Liberalized ASA and Its Impact

International air transport is associated with sovereignty among countries. In the 1944 Chicago Convention, representatives from fifty-two economies reached an agreement recognizing that "every state has complete and exclusive sovereignty over the airspace above its territory" (Article 1, Chapter I) and "no scheduled international air service may be operated over or into the territory of a contracting State, except with the special permission or other authorization of that State." (Article 6, Chapter II) That is, all international aviation routes would be governed by bilateral air service agreements (ASAs) between the departure and arrival countries. IATA estimated that there are more than 3,000 ASAs in the world and the top 200 are associated with 75% of international traffic (IATA, 2007).

Before the 1970's, the majority of ASAs regulated international air transport in a restrictive manner through operational restrictions (e.g., the number of airlines and flight frequency on a specific route) and ownership restrictions (e.g., designated airlines must be at least 75% owned by native citizens) (IATA, 2007). As globalization becomes a trend in the world, stronger demand for international travel and goods flow has resulted in more liberalized ASAs. The U.S. government has been an advocator of liberalization. After the failure to reach a multilateral agreement at the 1944 Chicago Convention, the

U.S. and the U.K. signed an important bilateral ASA, known as Bemuda I, in 1946. Bermuda I is designed in a liberal form which features no capacity limit on third and fourth freedoms, substantial fifth freedom rights, and free carrier designation (Oum, 1998). However, after thirty years of experience with Bermuda I, the U.K. considered that U.S. carriers together took well over half of UK-US market and terminated Bermuda I. Instead, in 1977, the U.K. negotiated a more restrictive bilateral, known as Bermuda II, which restricts access to London Heathrow airport and constrains the number of flights and the U.S. cities covered by direct flights.

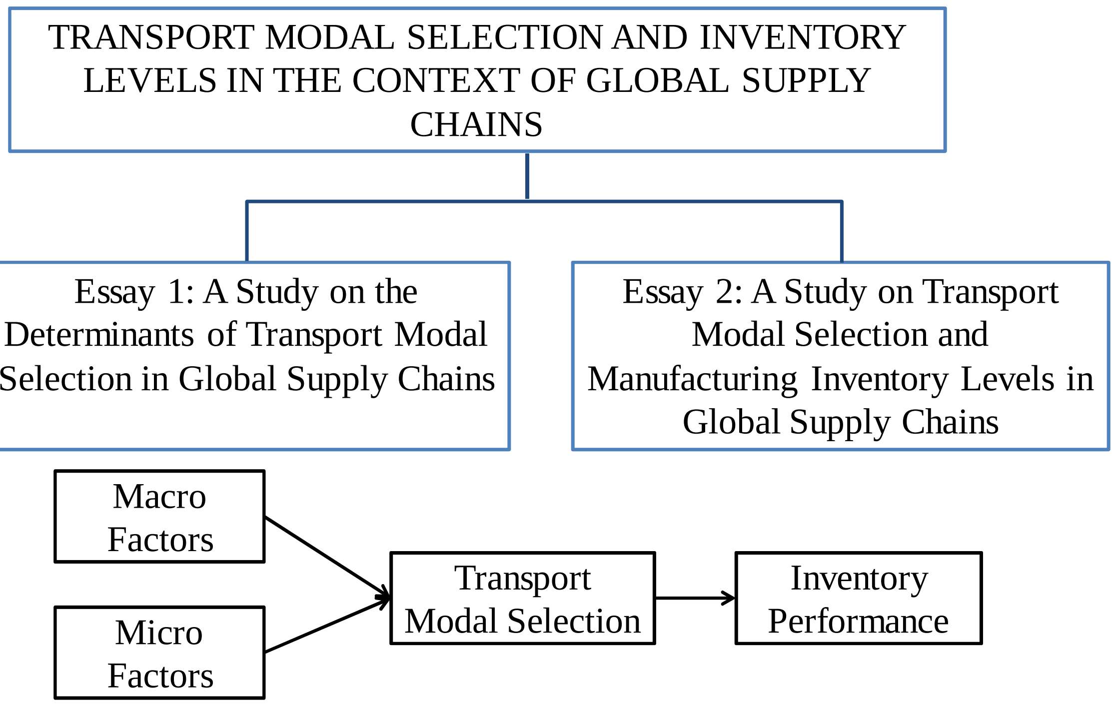
Believing that “maximum consumer benefits can best be achieved through the preservation and extension of competition between airlines in a fair market place” (International Air Transport Competition Act, 1979), the U.S. government advocated the pro-competitive policy and initiated deregulations in both domestic and international air transport markets in 1978. First, the U.S. initiated a liberalized U.S.-Netherlands bilateral ASA, which abolished the limits on the number of flights and airlines and dramatically expanded fifth freedom and cities covered by direct service on a reciprocal basis. Then, a series of liberalization efforts in the international sector was kicked off. During 1978 and 1982, the U.S. signed liberal agreements with 23 countries in Europe and Asia (Oum, 1998). The pro-competitive philosophy further led to the introduction of open skies agreements, which grant unconstrained fifth freedoms and allow completely free pricing and flexible code sharing in addition to unlimited flights, airlines, and routes. As of December 2011, the U.S. has signed open skies ASAs with 105 partners (U.S. Department of State, 2010). Based on an estimate of the ICAO secretariat (2009), about 31 percent of country-pair routes with non-stop scheduled service in the world were conducted under either regional liberalized or bilateral open skies ASAs in 2008, compared with 7 percent in 1998.

The literature on liberalization indicates that liberalized ASAs lead to more competition, lower prices, higher traffic growth, and eventually economic growth (Dresner and Windle, 1992; Maillebiau and Hansen, 1995; Marlin, 1995; Melville, 1998; Robyn et al., 2002; InterVISTAS, 2006; Fu et al., 2010). Several studies (Robyn et al., 2002; InterVISTAS, 2006; Fu et al., 2010) indicated that traffic growth from liberalization is driven by better service levels and lower fares. First, liberalized ASAs enable new and better services in terms of wider network coverage, more air service providers, higher flight frequency, and lower prices. Airlines are able to optimize their networks through hub-and-spoke systems, which expand service coverage to new destinations. Hence, the upgraded service levels stimulate market demand and contribute to traffic growth. In addition, liberalization increases competition, leading to lower fares which stimulate more traffic. Eventually, traffic growth contributes to economic growth in terms of four major impacts on the economy: 1) direct impacts due to increased employment and output of the air transport sector; 2) indirect impacts due to higher employment and output from tourism industry and airline-related producers and suppliers; 3) induced impacts driven by increased spending of people in related industries; and 4) enabling or catalytic effects on business operations and investments (InterVISTAS, 2006; IATA, 2008; Ishutkina and Hansmen, 2009; Fu et al., 2010). Liberalized ASAs contribute to more direct flights between two countries and lower fares, likely facilitating firms to use more air shipping in global supply chains. Based on the categorization above, this effect is considered a catalytic effect of liberalization.

1.3 Research Framework

This dissertation aims to answer the research questions in two essays. In the first essay, this study identifies and examines the factors that affect the decision of transport modal choice in global supply chains. In the second essay, this study examines the effects of air shipping on manufacturing inventories. The research framework is developed as follows (see Figure 1-1).

Figure 1-1 Theoretical Framework



In the first essay, this study examines the macro and micro factors that affect the decision of transport modal choice in global supply chains. The factors affecting modal decision are classified as the characteristics of industry, mode, shipment, and region. This study proposes that the decision maker of the modal choice aims to maximize its own profit and take the revenue drivers and cost drivers into account. The results show that both importers and exporters use more air shipping for high-value products and when there is a positive sales surprise. Large importers and exporters have a smaller proportion for air shipping compared with small ones. While an importer’s modal decision is highly associated with demand dynamics, an exporter’s decision is more determined by gross margin and cost of capital but less by demand variation. The managerial implications are discussed.

In the second essay, this study examines the effects of air share on manufacturing inventories. As globalization expands a firm's geographic coverage of business, the literature indicates that globalization has led to higher inventory levels due to longer supply chains. The experience in the U.S. domestic market showing that air transport plays a more important role in the practice of JIT after deregulation in 1978 could be applicable to global markets. This study finds that the usage of air shipping in export can effectively reduce manufacturers' inventory levels at a diminishing rate. In addition, transportation modal selection is associated with profit maximization. It is found that the demand variation contributes to more use of air shipping, while higher gross margins, cost of capital, and the relevance to timeliness facilitate firms to use air shipping to capture the demand and shorten the cash cycle. Furthermore, the industries with larger major players have higher shares of ocean shipping because of risk pooling advantages. The results are used to develop guidelines for transport modal decision including the breakeven point of carrying costs based on total cost minimization and optimal air shares based on profit maximization. This study reiterates that a firm should pursue profit maximization rather than total cost minimization only.

The rest of the dissertation is structured as follows. Chapter 2 reviews the academic literature concerning transport modal selection, inventory, bullwhip effect, and globalization. Chapter 3 presents the first essay which studies the determinants of transport modal selection in global supply chain. Chapter 4 presents the second essay which studies the relationship between shippers' transport modal decision and inventory levels. Chapter 5 concludes this study and identifies the opportunities for future research.

Chapter 2 Literature Review

2.1 Introduction

In previous chapter, I describe the motivation of this study and the research framework as well as background about the development of liberalized ASAs and their impact. In this chapter, I will review the literature relating to the subject of each essay. For Essay One, I review the literature about freight modal-split theories including aggregate models and disaggregate models. For Essay Two, I include the theories about inventory, bullwhip effect, and globalization. In the last section, research gaps and future opportunities are identified.

2.2 Freight Modal Split Theories

Traditionally freight transportation demand (FTD) studies are classified into two categories: aggregate models and disaggregate models. While aggregate models use the data aggregated at the commodity and/or regional level for different modes, disaggregate models focus on the modal choice pertaining to individual shipments or shippers (Winston, 1983, 1985; Zlatoper and Austrian, 1989; Regan and Garrido, 2002; De Jong et al., 2004). Most studies are analyzing the FTD for rail and truck intercity services, and only a few studies focus on air and sea-based international transport. The studies in these two categories are discussed below.

2.2.1 Aggregate FTD 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. (Boyer, 1977; Levin, 1978; Oum, 1979; Friedlaender and Spady, 1980; Hummels and Schaur, 2012). The shipment characteristics used in previous studies include the value per weight, the density, the price volatility, and the inventory costs of the commodity, and the relevance to timeliness (Friedlaender and Spady, 1980; Hummels and Schaur, 2010; Hummels and Schaur, 2012). The regional characteristics used in previous studies include the real interest rate and the variation in the exchange rate growth at the regional level (Hummels and Schaur, 2010).

Related aggregated FTD studies are summarized as follows. Levin (1978) studies the effect of ICC regulation on modal split among truck, rail boxcar, and piggyback for 42 manufactured commodities aggregated at the three-digit level. Based on the utility to a shipper of the chosen mode, Levin develops a logit model including only the modal characteristics. He uses the results to project welfare losses from regulation and finds the losses are substantially less than reported in early studies. Oum (1979) uses freight transportation data which consists of eight commodity groups, 4,692 Canadian interregional links, and rail and truck modes to study cross-sectional FTD in Canada. He derives an expenditure-share function from a link-specific unit transportation cost function with the independent variables including ton-mile freight rate, two quality-of-service variables (the average speed of the mode and the coefficient of variation of transit time), and distance in a general model and finds that shippers of high-value commodities emphasize quality of service more than those of low-value commodities. Friedlaender and Spady (1980) extend Oum’s study by allowing endogeneity between cost of transport and shipment characteristics. They argue that the full cost of transport including shipping charges and the inventory costs is a function of shipping rates and shipment characteristics such as the value per weight, the density, the average length of haul, and the average shipment size. The share of truck and rail services is determined by the full cost of transport, fixed inputs, capital, and output.

Furthermore, the FTD study has been extended to international transport. Hummels and Schaur (2010) study the relationship between demand uncertainty and faster transport in international trade and calculate the value of the faster transport option. Using the monthly U.S. Imports of Merchandise database during 1990-2004 aggregated at the HS (Harmonized System) 10-digit commodity and the country levels, they develop an air share model including modal characteristics like air and ocean charges, shipment characteristics like value-to-weight price, price volatility, and the number of shipments, country characteristics like real interest rates, variations in exchange rate growth, and the pipeline costs calculated by the product of real interest rate and average transit days in logarithm term. Through OLS and fixed effects techniques, they find that more volatility in price leads to a higher share of air shipping in imports. Furthermore, Hummels and Schaur (2012) use the monthly U.S. Imports of Merchandise database during 1991-2005 aggregated at the exporter, the US coastal districts, the HS 6-digit commodity, and the transportation mode levels to estimate the effects of customers' price elasticity of demand for international transport and their valuation of time saving on firms' modal choices. Through OLS and fixed effects techniques, they find one day in transit is valued at 0.6-2.3 percent of the tariff and the commodities associated with parts and components are sensitive to time and more likely to be shipped by air.

2.2.2 Disaggregate FTD Models

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. For example, Miklius, et al. (1976) use data from 1,374 shipments to estimate the elasticities and cross elasticities for the mode choice between rail and truck for shipping cherries and apples. They find that the probability of using rail service for cherries is negatively associated with transit time and freight rates of rail mode and is positively associated with those of the substitute mode at a 0.01 significance level. In addition, they find that shippers tend to use faster transportation for the commodity of high value and high perishability. Winston (1981) studies the intercity mode-choice decisions at the individual decision maker level from a shipper and a receiver's perspectives. He argues that when the shipper is a decision maker, his utility comes from low freight expense while a receiver emphasizes service quality. A modal decision is made based on the maximization of the joint expected utility of both parties. The utility of a decision maker is a function of observed factors like modal attributes, commodity and firm characteristics, and unobserved attributes like individual's taste and attitude toward risk. Using one data set which the receiver is the decision maker and another which the shipper makes the decision, he finds perishable goods and the products that require huge storage costs are very sensitive to service quality measured by the mean and the coefficient of variation of transit time. Jeffs and Hills (1990) conduct 100 interviews in the paper, printing, and publishing sector in the U.K. and survey the attributes that affect the modal choice of freight managers. Using factor analysis, these attributes are grouped into six factors: customer requirements, product characteristics, company structure/organization, government, available transport facilities, and decision maker.

- Customer requirements: size and frequency of delivery, timing of delivery, urgency of delivery, and specification of mode by customer;
- Product characteristics: value, volume to weight quotient, product type, handling characteristics, perishability;
- Company structure/organization: independence of establishment, number of organization levels, number of employees engaged in transport function, position of transport function in hierarchy, and sphere of operation;
- Government: transport infrastructure, and regulation;
- Available transport facilities: own fleet, availability of pubic modes for delivery operation;
- Decision maker: knowledge of alternatives and level of responsibility in company.

Furthermore, the disaggregate studies have been extended to international transport. Hayuth (1985), using surveys of importers and exporters in Israel, suggests four major factors that affect the competition between air freight and seaborne trade: cost, time, nature of good, and market characteristics.

- Cost: including costs of line haul, pickup and delivery, packing, refurbishing, insurance, and level of stocks;
- Time: total voyage time, distance from terminal, frequency of service, transshipment, and terminal handling;
- Nature of good: weight, density, value, perishability, and fragility;
- Market characteristics: demand variations, seasonality, urgency, inflation, and interest rates.

Generally, disaggregate mode choice models are considered better than aggregate models in terms of their preciseness (Winston, 1981). Because disaggregate studies conduct the analysis at an individual shipment level, they can capture the impact of freight charges and shipment characteristics on modal choice more precisely than aggregate studies (Zlatoper and Austrian, 1989). In addition, aggregate studies use average values, leading to the underestimation of the population response to the proposed change (Winston, 1981). However, because disaggregate studies 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. Considering the pros and cons of aggregate and disaggregate models, this study uses aggregate models to estimate the model of manufacturing firms' modal choice between air and sea based on two reasons. First, this study is conducted at a national and industry level, and hence aggregate models could be more appropriate. Second, it is challenging to access the information of individual shipments for international trade. Aggregate models allow a researcher to conduct a study with aggregate trade data.

2.3 Inventory Theories

This study surveys the literature about empirical inventory studies (see Table 2-1). Several studies have been conducted to examine the factors that affect inventory performance. For the overall trend of inventory in the U.S., Rajagopalan and Malhotra (2001) study trends in inventory ratios, the ratio of inventory value over material costs and value added at various stages: materials, work-in-process (WIP), and finished goods. They investigate twenty manufacturing industry sectors from 1961 to 1994 using industry-level inventory data from the U.S. Census Bureau while controlling for the growth of output in a sector. They find that total manufacturing inventory ratios appear to show a decreasing trend, with materials and WIP inventory ratios demonstrating greater decreases than finished goods inventory ratios in most industry sectors. Chen et al. (2005), using firm-level data from COMPUSTAT, examine the effect of inventory days, the ratio of inventory value times 365 days over cost of goods sold, on financial performance from 1981 to 2000 while controlling for interest rates, growth in GDP, inflation, and the optimism expressed by purchasing managers (PMI). They find that firms experienced declines in inventory-days, on average, by about 2% during the research period, with WIP inventory-days showing the largest decline at 6%, followed by materials at 3%. Chen et al. (2007) collect both firm-level data from COMPUSTAT and aggregate-level sales and inventory data from the U.S. Census Bureau for manufacturing, retail and wholesale sectors and compare the inventory patterns from these two sources. They find that wholesale inventory days dropped significantly from 1981 to 2004, while retail inventory did not decline until 1995, controlling for the same variables as those used by Chen et al. (2005).

For the effects of specific factors on inventory performance, Gaur et al. (2005) use firm-level financial data for 311 publicly-listed retail firms during the period 1987 to 2000 to examine how gross margin, capital intensity, and the ratio of actual sales to expected sales respond to inventory turnover (the ratio of cost of goods sold over inventory value). Their results show that lower inventory turnover is associated with higher gross margin, lower capital investment, and a lower ratio of actual sales to expected sales. Shah and Shin (2007) use sector-level data from the manufacturing, retail and wholesale sectors from the Bureau of Economic Analysis (BEA) from 1960 to 1999 and find that information technology (IT) investment contributes to improved financial performance through its impact on the inventory-to-sales ratio. Rumyantsev and Netessine (2007) use the quarterly data of 722 publicly listed U.S. companies to test the hypotheses derived from classical inventory models. With inventory turnover as the dependent variable, they find support for positive relationships with demand uncertainty, length of lead times, and gross margins, negative relationship with firm size, and a mixed result with inventory carrying costs. They find that the results still hold at the aggregate firm level. Han et al. (2008) study the effects of import ratios and export ratios on inventory days of raw material and finished goods, respectively while controlling for cost of capital, sector inflation, sector real growth, and the ratio of IT investment.

Table 2-1 Summary of Empirical Inventory Literature

Paper	Data	DV	IVs
Lieberman, Helper, and Demeester (1999)	Two surveys of automotive parts mfg plants	Inventory Ratios (=Inventory/Sales)	Product and process characteristics (general, functional, material, mfg. process), managerial factors (batch size, workforce, vertical communication, Japanese management)
Rajagopalan and Malhotra (2001)	1961-1994 20 industrial sectors (manufacturers) from U.S. Census Bureau	Material Inventory Ratio = Materials inventory/material cost	Time (T=year), $(T-T_0)X$, where (T_0 = 1980, X=dummy for year after 1980), Growth rate in output in a sector
		WIP Inventory Ratio = WIP inventory/(material cost+0.5*Value added)	Time (T=year), $(T-T_0)X$, where (T_0 = 1980, X=dummy for year after 1980), Growth rate in output in a sector
		FG Inventory Ratio = FG inventory/(material cost+value added)	Time (T=year), $(T-T_0)X$, where (T_0 = 1980, X=dummy for year after 1980), Growth rate in output in a sector
Gaur, Fisher, and Raman (2005)	1985-2000 311 U.S. listed Retailers, S&P Compustat database	log Inventory Turns (=COGS/Inv)	Gross Margin (=(S-COGS)/S), capital intensity (=Gross Fixed Assets/(Inv+GFA)), sales surprise (=S/sales forecast), CGS, firms fixed effects, year fixed effects
		log Inventory	Cost of Goods Sold, Gross Margin, Capital intensity, Sales surprise, Firms fixed effects, year fixed effects
Chen, Frank, and Wu (2005)	41000 firms over 20 years from COMPUSTAT	Inventory Days =Inv/COGS*365	Time (T=year), interest rate, GGDP, inflation, PMI
		Inventory-to-sales ratio = Inv/Sales	Time (T=year), interest rate, GGDP, inflation, PMI
		Inventory-to-asset ratio = Inv/Total assets	Time (T=year), interest rate, GGDP, inflation, PMI

Table 2-1 Summary of Empirical Inventory Literature (continued)

Paper	Data	DV	IVs
Rumyantsev and Netessine (2007)	1992-2002 722 U.S. public companies, S&P Compustat database	log Inventory	Cost of Goods Sold, Gross Margin, Days Account Payable (lead time), Sigma Sales (demand uncertainty), T Bill Rate (inventory holding cost), Positive Sales Surprise (sales shock), Sales Growth, Seasonality, Time trend
		log Inventory-COGS Ratio	Fixed Assets, Gross Margin, Days Account Payable, Sigma Sales, T-bill Rate Positive Sales Surprise, Sales Growth, Seasonality, Time trend
Han, Dresner, and Windle (2008)	2002-2005 19 30-digit US manufacturing sectors from ASM	RAW_Day = RM_Inventories/Cost of Material*365	ImportRatio(= imported raw materials/total cost of materials), ITRatio(= annual spending on compurter/total shipment value, capital cost, inflation, sector growth, shipment value, industry dummy, time dummy
		FG_Day = FG_Inventories/Shipment Value*365	ExportRatio(= Exported finished goods/total shipment value), ITRatio(= annual spending on compurter/total shipment value, capital cost, inflation, sector growth, shipment value, industry dummy, time dummy

2.4 Bullwhip Effect

The bullwhip effect describes the phenomenon that the variations of demand orders are amplified when they move up the supply chain (Lee et al. 1997a, 1997b). For example, Procter & Gamble (P&G) found much larger variations in the distributor's orders given that the variations in retailer's sales are not excessive. Consequences of the bullwhip effect are that supply chain members, especially those in the upstream, have to carry unnecessary inventories and spend additional operational costs to deal with the fluctuations in demand. Lee et al. (1997a, 1997b) indicate that demand forecasting update, order batching, price fluctuation, and rationing and shortage gaming cause the distortion of demand information, leading to the bullwhip effect. These causes are explained as follows.

First, the distortion of demand information occurs when firms develop demand forecasting based on the order history from their immediate customers. For example, the retailer may use a simple forecasting method like exponential smoothing to predict demand and issue orders. As a result, the order received by the manufacturer does not reflect the true demand in market. Such distortion will be further amplified when replenishment lead time is long and when the number of supply chain members increase.

Second, firms may consolidate demand and place orders at a large batch to save ordering costs and take advantage of economies of scale. As a result, the true demand is distorted. For example, the difference between full truck-load (FTL) and less than truckload (LTL) rates offers firms a strong incentive to consolidate their orders to truckload when they place orders to suppliers.

Third, the fluctuations in prices and promotional discounts provide firms with incentives to buy in advance. The consequence of forward buying is that firms stop buying for a long period until they deplete inventories. Hence, the true demand is distorted.

Fourth, when there is more demand than supply and a manufacturer rations supply to its customers, downstream customers may exaggerate their orders in order to get the amount they really need. Once the imbalance between demand and supply is relaxed, manufacturers can completely fulfill customers' orders which will be later cancelled by customers.

2.5 Globalization Theories

Globalization has facilitated the forming of global supply chains in which suppliers, manufacturers, distributors, and customers are integrated from different parts of the world. Fawcett (1992) classifies the reasons for a firm's going global into two categories: the factor-input global manufacturing strategy and the market-access strategy. In the factor-input global manufacturing strategy, a firm enhances its competitive advantage in its home market through acquiring the best input of lower cost or higher quality. The differences in factor price across countries due to different endowments offer an incentive for firms to allocate their value activities to those countries in which those activities can be conducted at lower costs (Yeaple, 2006). For example, Western firms procure raw materials from and outsource production to developing countries like China and Vietnam because of cheaper labor forces and better economies of scale. A survey shows that significant price/cost reduction is the primary reason leading to global sourcing, and that purchasing prices and total cost of ownership have decreased, on average, 15 percent and 11 percent, respectively due to global sourcing (Trent and

Monczka, 2003). In the market access strategy, a firm establishes its worldwide operations to establish a local presence and access to foreign markets. Protectionism and the regional free trade agreements such as NAFTA (The North American Free Trade Agreement), EU (The European Union), and ASEAN (The Association of Southeast Asian Nations) have facilitated firms establishing production bases in foreign countries in order to overcome the protectionist practices like quotas, domestic content regulations, and tariffs (Fawcett, 1992).

Despite the advantages of a firm's going global, people usually have overlooked the costs of globalization (Levy, 1995, 1997; Rajagopalan and Malhotra, 2001; Trent and Monczka, 2003; Han et al., 2008; Cerruti, 2008). Lengthened supply chains and prolonged lead times due to globalization have increased uncertainties as well as transaction costs in supply chains. Several kinds of uncertainty are associated with longer lead times. First, market demand is more predictable for a shorter period compared with a longer period (Levy 1997). For example, it is easier to predict customers' demand of next week and more difficult to accurately predict demand in a specific week of next quarter. Second, because more incidents may occur and cause supply chain disruption for a longer period, there is a higher uncertainty for longer lead times. Third, the risks of depreciation in product value due to the fluctuations in exchange rates, raw material prices, and component prices are higher for a longer period.

Several studies find support for the disadvantages of globalization. Many firms report that their delivery cycle times have increased five percent on average due to global sourcing (Trent and Monczka, 2003). Because of longer lead times, firms have to prepare more inventories in response to the demand and demand variations during lead times.

Rajagopalan and Malhotra (2001) argue that U.S. manufacturers may have increased their material inventories as buffers to mitigate the risk of longer and more variable lead times when they increase their import ratios. In addition, they argued that increased U.S. exports may lead to less frequent shipments and thus higher inventory levels of finished-goods. Han et al. (2008), using trade and inventory data at an industry level from the U.S. Census Bureau during 2002-2005, find that an increase in import ratio, which is calculated by import value over total cost of materials, by 10 percentage points leads to a 2.16-day or an $800 million increase in raw material inventories. Furthermore, a 10 percentage point increase in export ratio, which is calculated by export value over total shipment value, is associated with a 2.05-day or $1.4 billion increase in finished goods inventories.

The literature indicates research gaps as follows. First, the modal choice decision is associated with not only the freight costs and the shipment characteristics but also the characteristics of industry that shippers and consignees belong to. Because transportation links the operations between shippers and consignees, the selection of transportation mode will have a direct impact on the operational performances of these two parties. Thus, it is crucial to consider the revenue and cost drivers that compose the decision maker’s profit in the modal decision. However, the FTD studies rarely take these factors into consideration (Miklius, et al., 1976; Boyer, 1977; Levin, 1978; Oum, 1979; Friedlaender and Spady, 1980). Second, most FTD studies focus on the modal split between truck and rail in a domestic market. As globalization increases the demand for international transport in global supply chains, it is important to examine the factors that affect the modal choices in an international context. Third, empirical inventory studies are dedicated to identifying the factors affecting firms' inventory performance. Despite the important role transportation has played in supply chains, few studies take transport mode into consideration. Given that transportation has a direct impact on firms' in-transit inventories and an indirect impact on safety stock, it is crucial to study the impact of transport mode on inventory levels.

Chapter 3 Essay One: A Study on the Determinants of Transport Modal Selection in Global Supply Chains

3.1 Introduction

Air shipping has been considered the most 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. During 1975-2004, the volume of worldwide air cargo shipments has been growing at a 7.4 percent annualized rate, compared with ocean's 4.5 percent (Hummels, 2007). From 1965 to 2004, the air share in the U.S imports increased 23.4 percentage points. As of 2004, air shipments in the U.S. exports have increased by 40.9 percentage points for the U.S. exports and account for over half of exports (Hummels, 2007). Why do firms use more air shipping in past decades despite higher costs?

Some studies are dedicated to finding the reasons contributing to the increased use of air transport. First, the cost of air freight has declined much more than that of sea freight due to technological change such as the adoption of jet engines (Gordon, 1990; Hummels, 2007). In addition, the ICT (information and communication technology) products, usually of higher value and lighter weight, in international trade have accounted for a significant portion of the growth in international trade over the past two decades, increasing value-to-weight ratios and the use of air shipping (Hummels, 2009). Furthermore, globalization has increased the demand for faster and more reliable movements of cargo across regions, nourishing the growth of air cargo (Su et al., 2011).

Nevertheless, because global transportation links the operations between shippers and consignees in two countries, the selection of transportation mode will inevitably have a direct impact on the operational performance of the decision maker and its counterpart. The decision on transport mode is not only based on the shipping costs and commodity type but also the connection to the maximization of the decision maker's profit. 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 asks three research questions. What are the revenue drivers and cost drivers contributing to the transport modal decision in global supply chains? To what extent do these drivers affect the modal decision? Do these drivers have a distinct impact on the modal decision for imports and exports? Using the trade data between the U.S. and 10 Asian trade partners and the annual survey data of the U.S. manufacturers, this study examines the determinants that affect the transport modal selection of U.S. exporters and importers in global supply chains. This study aims to have both academic and managerial contributions. Academically, this study is among a few papers that considers the revenue and cost drivers of decision makers in the transport modal selection. In addition, unlike the previous studies in the freight transportation demand literature which mainly consists of the modal choice between rail and truck for intercity services, this study fills a research gap by estimating the modal selection in a global context. For logistics managers, this study may inspire them to manage global transportation from the perspective of profit maximization.

3.2 Literature Review

Traditionally freight transportation demand (FTD) studies are classified into two categories: aggregate models and disaggregate models. While aggregate models use the data aggregated at the commodity and/or regional level for different modes, disaggregate models focus on the modal choice pertaining to individual shipments or shippers (Winston, 1983, 1985; Zlatoper and Austrian, 1989; Regan and Garrido, 2002; De Jong et al., 2004). Most studies are analyzing the FTD for rail and truck intercity services, and only a few studies focus on air and sea-based international transport. The studies in these two categories are discussed below.

3.2.1 Aggregate FTD 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 (Boyer, 1977; Levin, 1978; Oum, 1979; Friedlaender and Spady, 1980; Hummels and 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 and Spady, 1980; Hummels and Schaur, 2010; Hummels and Schaur, 2012). The regional characteristics used in previous studies include the real interest rate and the variation in the exchange rate growth at the regional level (Hummels and Schaur, 2010).

Related aggregated FTD studies are summarized as follows, and more details about each aggregated FTD study are included in Chapter 2. Levin (1978) develops a logit model including the modal characteristics to study the effect of ICC regulation on modal split among truck, rail boxcar, and piggyback for 42 manufactured commodities aggregated at the three-digit level. Oum (1979) derives an expenditure-share function from a link-specific unit transportation cost function with the independent variables including ton-mile freight rate, two quality-of-service variables (the average speed of the mode and the coefficient of variation of transit time), and distance in a general model to study cross-sectional FTD in Canada. Friedlaender and Spady (1980) consider endogeneity between cost of transport and shipment characteristics and find that the share of truck and rail services is determined by the full cost of transport, fixed inputs, capital, and output.

Furthermore, the FTD study has been extended to international transport. Hummels and Schaur (2010) study the relationship between demand uncertainty and faster transport in international trade. Using the monthly U.S. Imports of Merchandise database during 1990-2004 aggregated at the HS (Harmonized System) 10-digit commodity and the country levels, they develop an air share model including modal characteristics like air and ocean charges, shipment characteristics like value-to-weight price, price volatility, and the number of shipments, country characteristics like real interest rates, variations in exchange rate growth, and the pipeline costs calculated by the product of real interest rate and average transit days in logarithm term. Through OLS and fixed effects techniques, they find that more volatility in price leads to a higher share of air shipping in imports. Furthermore, Hummels and Schaur (2012) use the monthly U.S. Imports of Merchandise database during 1991-2005 aggregated at the exporter, the US coastal districts, the HS 6-digit commodity, and the transportation mode levels to estimate the effects of customers' price elasticity of demand for international transport and their valuation of time saving on firms' modal choices. Through OLS and fixed effects techniques, they find one day in transit is valued at 0.6-2.3 percent of the tariff and the commodities associated with parts and components are sensitive to time and more likely to be shipped by air.

3.2.2 Disaggregate FTD Models

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.

The related disaggregate studies are summarized as follows. More details are included in Chapter 2. Miklius, et al. (1976) estimate the elasticities and cross elasticities for the mode choice between rail and truck for shipping cherries and apples by 1,374 shipment data with the information of transit time, freight rates, product value, and high perishability. Winston (1981) argues that a modal decision is made based on the maximization of the joint expected utility of both shipper and consignee. The utility of a decision maker is a function of observed factors like modal attributes, commodity and firm characteristics, and unobserved attributes like individual's taste and attitude toward risk. Jeffs and Hills (1990) survey the attributes that affect the modal choice of freight managers and group them into six factors: customer requirements, product characteristics, company structure/organization, government, available transport facilities, and decision maker. In a disaggregate studies on international transport, Hayuth (1985) suggests four major factors that affect the competition between air freight and seaborne trade, including cost, time, nature of good, and market characteristics.

Generally, disaggregate mode choice models are considered better than aggregate models in terms of their preciseness (Winston, 1981). Because disaggregate studies conduct the analysis at an individual shipment level, they can capture the impact of freight charges and shipment characteristics on modal choice more precisely than aggregate studies (Zlatoper and Austrian, 1989). In addition, aggregate studies use average values, leading to the underestimation of the population response to the proposed change (Winston, 1981). However, because disaggregate studies 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. Considering the pros and cons of aggregate and disaggregate models, this study uses aggregate models to estimate the model of manufacturing firms' modal choice between air and sea based on two reasons. First, this study is conducted at a national and industry level, and hence aggregate models could be more appropriate. Second, it is challenging to access the information of individual shipments for international trade. Aggregate models allow a researcher to conduct a study with aggregate trade data.

The literature indicates two research gaps. First, the modal choice decision is associated with not only the freight costs and the shipment characteristics but also the characteristics of shippers. Because transportation links the operations between shippers and consignees, the selection of transportation mode will have a direct impact on the operational performances of these two parties. Thus, it is crucial to consider the revenue and cost drivers that compose the decision maker's profit in the modal decision. However, the FTD studies rarely take these factors into consideration (Miklius, et al., 1976; Boyer, 1977; Levin, 1978; Oum, 1979; Friedlaender and Spady, 1980). In addition, most FTD studies focus on the modal split between truck and rail in a domestic market. As globalization increases the demand for international transport in global supply chains, it is important to examine the factors that affect the modal choices in an international context. This study aims to develop a model that considers the modal and regional characteristics as well as the components of profit in the estimation of the modal selection in international transport.

3.3 Theory and Hypotheses Development

The classic 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).

$$\pi = TR - TC \tag{1}$$

The calculation of total revenue, equal to the product of the selling price (P) and the quantity sold (Q), is straight forward. The higher price and the more quantity sold (or fewer sales loss), the more revenue earned by a firm. The quantity sold is determined by the population, the selling price, the price of substitutes, and the availability of the product.

$$TR = PQ \tag{2}$$

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

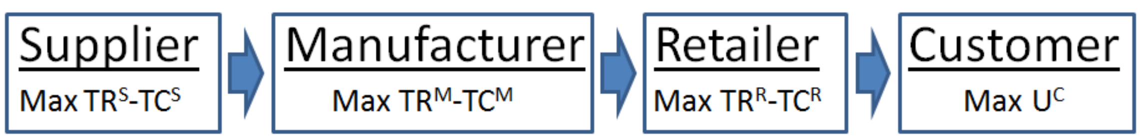
The function of total cost is more complex. Output is a function of inputs including capital (K), labor (L), materials (M), air transport (A), ocean transport (O), technology (t), and quality of inputs ($\overline{X}$), while total cost is a function of output (Y), input prices such as the costs of capital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

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

$$TC = h(Y, R^K, R^L, R^M, R^A, R^O, t) \tag{5}$$

In a supply chain, supply chain members have separate revenue functions and cost functions and want to maximize their own profits, while customers want to maximize their utilities (see Figure 3-1). Transportation links the operations activities between supply chain members, and the decision makers of modal selection intend to maximize their own profits, which is the difference between revenue and cost. It does not necessarily mean that the decision maker will choose the transport mode of the lowest freight cost, because the use of low-cost and slow transport may risk shipment delays and low service quality, backfiring to the shipper with sales loss. Instead, a decision maker has to take both the revenue and cost drivers into account. In the following sections, I will describe how the revenue and cost drivers affect the transport modal selection.

Figure 3-1 Objectives of Members in A Supply Chain



3.3.1 Revenue Drivers and Modal Selection

In the following two sections, I use two examples to explain how the revenue drivers and costs drivers affect modal decisions of importers and exporters. In this study, the same drivers are proposed for exporters and importers. However, the ways that they affect modal decisions are slightly different. In the following sections, an “a” is attached for the hypotheses related to importers and a “b” for those related to exporters.

To begin with, I take Apple Inc. (called Apple in the following discussion) as an example to explain an importer’s transport modal selection. Apple, a California-based company renowned for its consumer electronic products such as iPad and iPhone, has outsourced its production activities to its OEM (original equipment manufacturing) partner like Foxconn Technology (called Foxconn in the following discussion), a Taiwanese manufacturer with factories in China. For the domestic sales of iPad 3 in the U.S., Apple has to import finished goods from Foxconn in China to the U.S. Referring to Figure 3-1, Apple is a manufacturer which imports finished goods from its supplier, Foxconn. Also, Apple is the decision maker for choosing transport mode, either ocean or air, and pays the freight cost to carriers. How does Apple make the decision of modal choice considering both revenue and cost?

Several attributes contributing to revenue could affect the transport modal selection. As shown in Equation 2, the revenue of a firm is the product of selling price and quantity sold. One of the approaches that a firm uses to maximize its profit is to increase revenue; meanwhile, it also wants to decrease the sales loss, measured by the gross margin and the quantity of unfilled orders, because of insufficient inventories on hand. The existence of demand uncertainty could make managing the sales loss more challenging. Fluctuating demand makes accurate forecasts more difficult, and a firm could encounter the problems of either high obsolescence cost or high sales loss. Because transportation offers the utilities of place and time for a firm to realize demand on time, the choice of transport mode could be determined by the revenue drivers including price, gross margin, and demand uncertainty.

First, price, or the value of product, could affect the modal selection. Because the shipping charge is primarily calculated by weight except for insurance and handling fees, given the same weight, the freight cost for a high-value item accounts for a smaller portion of the product value compared with that for a low-value item. For example, assume that the air shipping cost of an iPad 3 from China to the U.S. is $10 compared with $5 by ocean. For a $500 iPad, the cost increase of switching from ocean to air is equivalent to 1 percent of the original price. But for a $50 iPad accessory at the same weight, the switching implies a 10 percent increase in the price. Hence, Apple may prefer using air transport for importing a $500 iPad rather than a $50 iPad accessory. It is hypothesized that importers use more air shipping for high-value items. Hypotheses 1a is developed as follows.

H1a: For importers, the share of air transport in trade is positively associated with the value of the product.

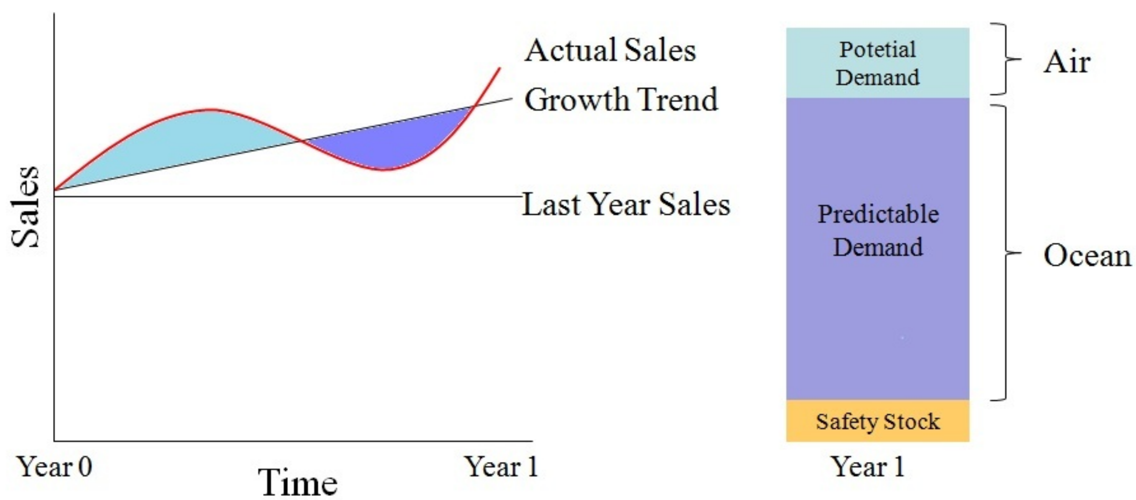
Second, the gross margin could affect the transport modal decision. In inventory theory, the gross margin is a measure of underage cost, and high gross margin implies higher sales losses caused by unmet demand. For the commodity of high gross margin, it offers firms incentives to realize demand through faster transportation. Additionally, similar to the effect of high value, the cost of air shipping accounts for a smaller portion of profit for high gross-margin products, making air shipping more affordable. Hence, it is hypothesized that importers use more air shipping for high-gross-margin items. Hypothesis 2a is developed as follows.

H2a: For importers, the share of air transport in trade is positively associated with their gross margin.

Third, demand uncertainty could have impact on both revenue and cost of firms and affect their choice of transport mode. When a firm develops its forecast towards next year, the historical trend of sales is a baseline (see Figure 3-2). 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 longer transit time and lower transpiration costs. Once the market demand surges above expectation, to minimize the sales loss and customer churns, a firm may use faster transportation such as air shipping to fulfill the unexpected orders. As demonstrated in Equations 2 and 3, the revenue is determined by the quantity sold, while the quantity depends on availability. To increase revenue, a firm may increase the product availability by using faster transportation to replenish the inventory when demand is higher than expectation. That is, a positive sales surprise, which is the percentage of demand over the historical trend, may facilitate a firm's decision on using more air shipping. Hypothesis 3a is developed as follows.

H3a: For importers, their share of air transport in trade is positively associated with the positive sales surprise.

Figure 3-2 Classification of Demand Based on Uncertainty



3.3.2 Cost Drivers and Modal Selection

As demonstrated in Equations 4 and 5, classic economic theory indicates that total cost is a function of output and input prices, while output is a function of inputs and changes in technology. In the example of Apple and iPad 3, the number of iPad 3s produced and imported to the U.S. is the output. For producing iPad 3, Apple has to invest capital, labor, materials, and technology to build the production capacity which is offered by its OEM partner, Foxconn, and deliver the finished goods to the market. If the demand is highly fluctuating, it will result in inaccurate forecasts and thus improper levels of investment in inputs. Thus, a firm may use different transport modes to reduce the impact of demand uncertainty. In addition, in acquiring the capital needed for investment, Apple may borrow money from banks, issue bonds, or raise funds from stockholders. The interests paid to banks and bondholders and the dividends paid to stockholders are considered Apple's cost of capital. Furthermore, to import finished goods of iPad 3s, Apple has to pay for the shipping charges to either air or ocean service providers. The cost of capital and shipping charges are prices of Apple's inputs. The objective of Apple is to maximize the profit by achieving its sales target while managing the inventories and related costs at reasonable levels. Because transportation offers Apple the utilities of place and time to realize demand on time, the choice of transport mode could be determined by the cost drivers including cost of capital and demand uncertainty.

First, the cost of capital could affect the choice of transport mode. One approach to measure the requirement for working capital is 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 well as the cost of capital. Because ocean shipping, which features large quantity and long transit time, carries 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 cost of capital. Hence, it is hypothesized that importers use more air shipping when their costs of capital are high. Hypothesis 4a is developed as follows.

H4a: For importers, their share of air transport in trade is positively associated with their cost of capital.

Second, as mentioned earlier, demand variation may affect the costs of firms and have an impact on their modal decisions. High demand variation may imply 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 variations in lead time and demand as follows (Tersine, 1994).

$$\text{Safety Stock} = \mathrm{k}\sigma = \mathrm{k}\sqrt{\mathrm{L}\sigma_D^2 + \sigma_L^2 D^2} \tag{6}$$

where k = safety factor based on customer service level, σ = standard deviation of demand during lead time, L = average lead time, σ_D = standard deviation of demand, σ_L = standard deviation of lead time, D = average demand.

High demand variation (σ_D) leads to more safety stock at the same service level. Evers (1999) finds that as the coefficient of variation in demand (σ_D) increases, the option of shorter lead times (L) becomes more attractive. Using faster transportation like air shipping shortens the replenishment lead time (L) so that the demand variation during lead time (σ) is lower, and hence a firm can keep a lower inventory level at the same service level. Hummels and Schaurs (2010) find that higher price volatility, measured by the coefficient of variations in product values in a year, is associated with more usage of air shipping in imports, implying the linkage between demand uncertainty and faster transportation. In this study, it is hypothesized that firms in an industry with high demand variation tend to use more air shipping. Hypothesis 5a is developed as follows.

H5a: For importers, their share of air transport in trade is positively associated with demand variation.

Third, the size of a firm may have an impact on the modal selection. Because large firms have a relatively larger customer base, the variations in demand at different locations may cancel each other out when demand is aggregated across different locations. Hence, large firms can use risk pooling strategies to lower the demand variation at an aggregate level. For example, Apple has hundreds of Apple Stores across the U.S. Even though some Apple Stores in California have poor sales performance for iPad 3s, some in New York may perform well and cancel out the impact from California. Hence, Apple could consolidate the demand in California and New York and import the quantity as predicted. Rumyantsev and Netessine (2007) indicate that larger firms keep lower inventory levels because of lower aggregate demand variation by risk pooling. Similarly, larger firms may take advantage of risk pooling to lower demand variation and increase the predictability of demand. Thus, larger firms may use more ocean shipping. In addition, larger firms have a higher bargaining power over their customers. Hence, they could be able to negotiate a more favorable contract and promise a later delivery date. Hypothesis 6a is developed as follows.

H6a: For importers, their share of air transport in trade is negatively associated with firm size.

3.3.3 Modal Selection of Exporters

The theory above is also applicable to the decision makers who are exporters. I take General Electric Healthcare (called GE Healthcare in the following discussion), as another example. GE Healthcare is a U.S. manufacturer that makes high-price and sophisticated medical gear such as CT (computed tomography) scanners, MRI (magnetic resonance imaging) machines, and PET (position emission tomography) scanners. About 62% of GE Healthcare's products are made in U.S. plants (Dolan, 2004). Referring to Figure 3-1, GE Healthcare is a manufacturer and its customers could be retailers or end users in other countries.

For the goods exported to GE Healthcare's customers in Asia, the modal choice could be determined by the value of product. Among the products of GE Healthcare, a portable ultrasound machine and a patient monitor have similar weights at 12 pounds. The shipping charge is about $2/unit for ocean and $12/unit for air from the U.S. to Japan. The unit price for a portable ultrasound machine is $34,900 and a patient monitor is $7,000. A switch from ocean to air implies a 0.03% increase in the delivered cost for a portable ultrasound machine but a 0.14% increase for a patient monitor. Thus, GE Healthcare is more likely to use air shipping for exporting a portable ultrasound machine which has the higher value. Hypothesis 1b is developed as follows.

H1b: For exporters, the share of air transport in trade is positively associated with the value of the product.

For exporters, it takes a longer time to fulfill the demand in other countries compared with domestic demand. If there are unexpected demand surges in oversea markets, the gross margins may become an important criterion for GE Healthcare to choose transport modes. For high gross-margin items, the impact on profits from sales loss is higher and hence GE Healthcare is more likely to use faster transportation to realize as much demand as possible. For the low gross-margin items, GE Healthcare may allow backorders and accept some sales losses. Hence, Hypothesis 2b is developed as follows.

H2b: For exporters, the share of air transport in trade is positively associated with gross margin.

In addition, when the exporters find that the orders are higher than the historical trend, it means that their customers in some countries or domestic markets may have unexpectedly lower inventory levels or expect stronger demand growth in the near future. Therefore, the exporters' customers are likely to request a tight deadline for order fulfillment and/or pay the premium to use faster transportation. Hence, it is hypothesized that the exporters will use more air shipping when there are positive sales surprises. Hypothesis 3b is developed as follows.

H3b: For exporters, their share of air transport in trade is positively associated with positive sales surprise.

The cost of capital may affect exporters' modal decisions. Like importers, exporters are eager to collect cash from customers faster if the exporters have high costs of capital. One way to shorten the cash-to-cash cycle is to reduce the inventory days by delivering to the customers in other countries faster. Another benefit of using air shipping on a regular basis is the lower inventory levels at the exporter side. Because air transport has more frequencies and smaller lot size than ocean transport, the shipper could keep lower inventory levels while increasing the freight costs and ordering costs if they keep using air shipping on a regular basis. For high-value products, the decrease in inventory carrying costs including cost of capital could easily offset the increase in freight costs and ordering costs. Hence, it is hypothesized that exporters may use more air shipping when their costs of capital are high. Hypothesis 4b is developed as follows.

H4b: For exporters, their share of air transport in trade is positively associated with their cost of capital.

Demand variation may affect exporters' modal decisions. Like importers, given the same service level, exporters have to keep more safety stock if the demand variation is high. As indicated by Evers (1999), faster transportation becomes more attractive when demand variation is high. Because long replenishment lead time increases the demand variation during lead time, the switch from ocean to air could shorten the lead time and decrease the level of demand variation during the lead time. Hence, the exporters do not have to increase safety stock in response to high demand variation. Accordingly, it is hypothesized that exporters use more air shipping when the demand variation is high. Hypothesis 5b is developed as follows.

H5b: For exporters, their share of air transport in trade is positively associated with demand variation.

The size of exporters could affect their modal selection. A big exporter has relatively more customers in one country compared with a small exporter. Hence, the big exporter could use risk pooling to aggregate the demand in one country and decrease the impact of fluctuating demand. Then, a big exporter could consolidate the demand of different customers in one country and deliver the quantity as planned. Therefore, the big exporter could use ocean shipping with longer transit time, cheaper freight costs, and larger lot sizes and break bulk into separate shipments at the destination. In contrast, a small exporter has a smaller customer basis in one country. A change in demand from one single customer can hardly be offset by other customers. In addition, a small customer base makes it more difficult to fill a container for ocean shipping and thus their shipping costs are higher. For small exporters, the differences in shipping charges between air and ocean are smaller than those for big exporters. In addition, big exporters enjoy a higher bargaining power over their customers and could impose a longer replenishment lead time in the contract. Therefore, it is hypothesized that big exporters use more ocean shipping in exports. Hypothesis 6b is developed as follows.

H6b: For exporters, their share of air transport in trade is negatively associated with firm size.

3.4 Estimation Model and Data

To test the hypotheses, I survey the factors affecting the decision of transport mode choice from the theory discussed above and the literature and classify these factors into four categories: the characteristics of industry, transport mode, shipment, and region. The characteristics of industry are the focus of this study, including revenue drivers such as value of product (VW_RATIO), gross margins (GM), and positive sales surprise (PSURPRISE) and the cost drivers like cost of capital (CAPITAL), demand variations (CVD), and firm size (SIZE).

In addition, the characteristics of transport mode used in the FTD studies include the differences in shipping rates and transit time, and the variations of transit time (Boyer, 1977; Levin, 1978; Oum, 1979; Friedlaender and Spady, 1980; Hummels and Schaur, 2012). In this study, the ratio of air-to-ocean shipping rates (AO_RATIO) and the difference in transit time (TT_DIFF) are included in the estimation model.

Furthermore, the shipment characteristics include the shipment size, the length of haul, the density, the volatility of product prices, and the relevance to timeliness based on the literature (Friedlaender and Spady, 1980; Hummels and Schaur, 2010; Hummels and Schaur, 2012). Hummels and Schaur (2012) find that the parts and components are the intermediate inputs of production and relevant to the timeliness in the manufacturing process. If an exporter's product is a component which is an intermediate input of the downstream production, a poor on-time performance may lead to shutdown in the manufacturing process. Hence, the downstream customers will be willing to pay more to get the shipments on time. Hence, the component products are associated with a higher share of air shipping in trade. Considering the data availability and the relevance to this study, I include the commodity's relevance to timeliness (TIMELINESS) in the estimation model.

There are two methods to account for regional variations. Regional characteristics used in previous studies include the real interest rate and the variation in the exchange rate growth at the regional level (Hummels and Schaur, 2010). Alternatively, country variables are included in the model to account for the regional differences in the infrastructure, the income level, and the air service availability. In this study, regional variables such as real interest rate, GDP per capita, and frequency of direct flights are used to control for the regional differences.

Accordingly, the function of air share is developed for both the imports to the U.S. and the exports from the U.S. as follows.

Modal Choice = f (Industry Characteristics, Modal Characteristics, Shipment Characteristics, Regional Characteristics) (7)

Industry Characteristics = {Revenue Drivers, Cost Drivers}

= {value of product, gross margins, and positive sales surprise, cost of capital, demand variation, firm size} (8)

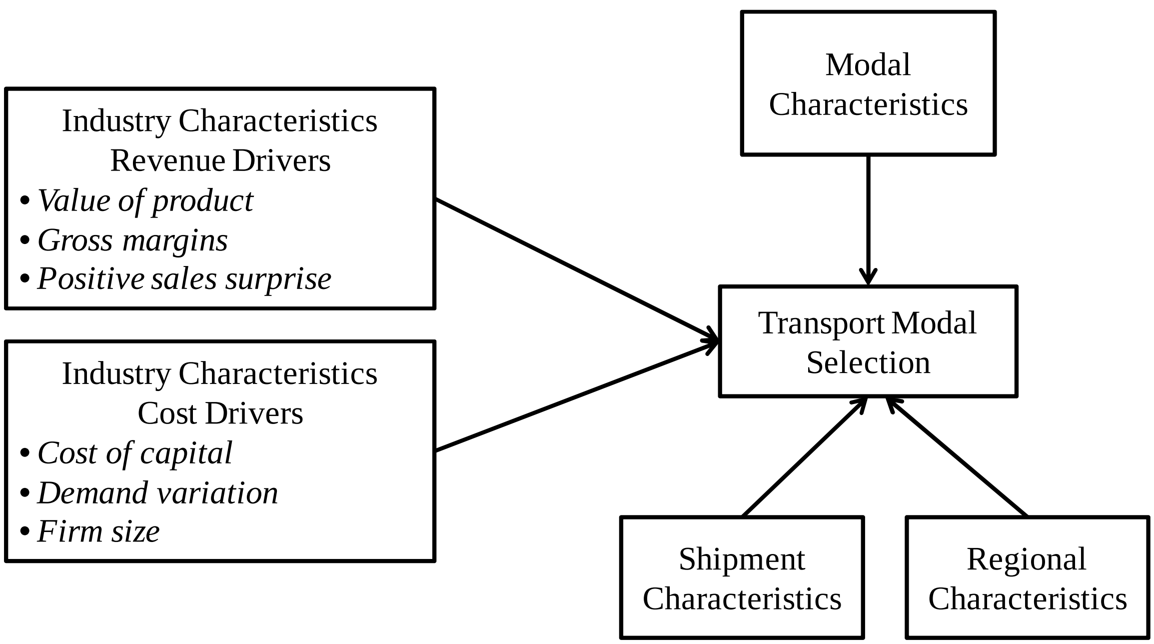
Modal Characteristics = {the ratio of air-to-ocean shipping rates, the difference in transit time}

Shipment Characteristics = {commodity's relevance to timeliness} (9)

Regional Characteristics = {real interest rate, GDP per capita, frequency of direct flights} (10)

The research framework is developed as Figure 3-3.

Figure 3-3 Research Framework of Essay One



To collect the data about modal choices in global supply chains, this study retrieves the trade data from the U.S. exporters/importers of merchandise database published by the U.S. Census Bureau during 2002-2009. This database provides rich information about the import and export trade at the 10-digit HS (Harmonized System) codes commodity level including value, weight, import shipping charges, transport mode, and origin/destination country on a monthly basis. The HS code, developed by the World Customs Organization (WCO), is an internationally standardized system of numbers and names for classifying traded products. Using a concord table offered by the U.S. Census Bureau, the product-based HS code can be converted to the industry-based NAICS (North American Industry Classification System) code. The NAICS system employs a 6-digit code at the most detailed industry level and is used by U.S. Federal statistical agencies in classifying business establishments for collecting data related to the U.S. business economy. Therefore, the linkage between traded products and the industry characteristics of importers and exporters is established through the concord table. In this study, the trade data is aggregated at the 3-digit NAICS level.

Furthermore, as demonstrated in Figure 3-1, there are several possible supply chain links in a global supply chain, such as supplier-manufacturer, manufacturer-retailer, and retailer-customers. To be more specific in the analysis and subject to the data availability, this study uses only the trade data related to the U.S. manufacturers which NAICS code is 31, 32, and 33. That is, for the imports, this study focuses only on the U.S. manufacturers' modal decision for importing from the oversea suppliers. For the exports, I take two scenarios into consideration. Assuming that the U.S. shippers are the decision maker in the transport modal choice, one scenario is that the U.S. manufacturers export their products to the oversea retailers, another is that the U.S. suppliers, also manufacturers in nature, export their products to the oversea manufacturers for further processing. Both scenarios for exporters are included in this study.

A question could be when are the U.S. manufacturers the decision makers in the modal selection for both imports and exports? What if the U.S. manufacturers are not the decision makers? First of all, in practice, both exporters and importers could be the decision makers of modal selection. The responsibility of international shipping is defined by the Incoterms (International Commercial Terms) (see Table 3-1). For example, the exporter (or seller) is in charge of shipping in the C.I.F. (Cost, Insurance and Freight) term, while the importer (or buyer) is the decision maker in the F.O.B. (Free on Board) term. However, it is possible that the U.S. manufacturers are not the decision makers in international shipping and just follow the instruction of its customer on modal selection. Subject to the data availability, this study covers only the scenarios in which U.S. manufacturers are decision makers and leaves other scenarios for future research.

Table 3-1 Types of Incoterms and Duties of Buyer/Seller

Incoterm	Loading on truck (carrier)	Export-Customs declaration	Carriage to port of export	Unloading of truck in port of export	Loading charges in port of export	Carriage to port of import	Unloading charges in port of import	Loading on truck in port of import	Carriage to place of destination	Insurance	Import customs clearance	Importtaxes
EXW	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer
FCA	Seller	Seller	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer
FAS	Seller	Seller	Seller	Seller	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer
FOB	Seller	Seller	Seller	Seller	Seller	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer
CFR	Seller	Seller	Seller	Seller	Seller	Seller	Buyer	Buyer	Buyer	Buyer	Buyer	Buyer
CIF	Seller	Seller	Seller	Seller	Seller	Seller	Buyer	Buyer	Buyer	Seller	Buyer	Buyer
DAT	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Buyer	Buyer	Buyer	Buyer	Buyer
DAP	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Buyer	Buyer	Buyer
CPT	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Buyer	Buyer	Buyer
CIP	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Buyer	Buyer
DDP	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Seller	Buyer	Seller	Seller

Origin → **Destination**

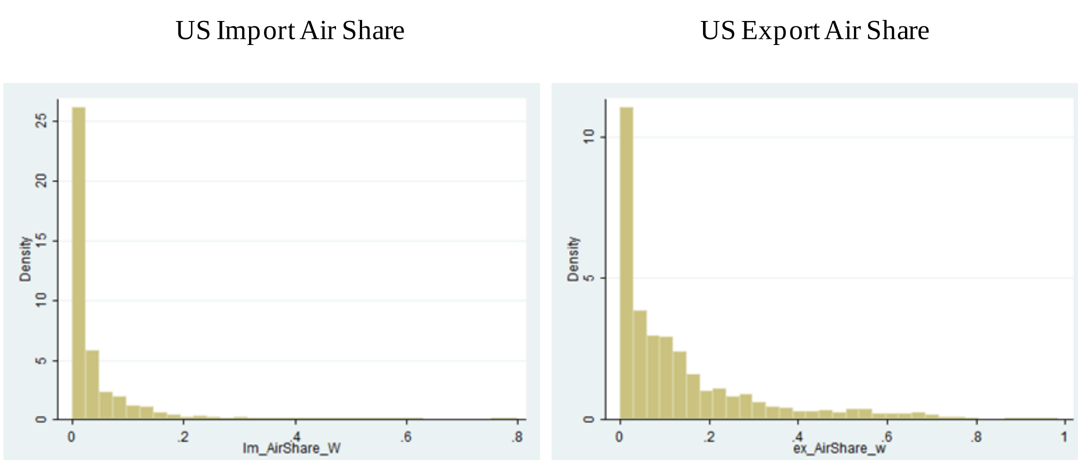
Source: International Chamber of Commerce (2012)

In addition, this study focus 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 for the following reasons. First, this study excludes the countries in North and South America because the transportation in this region heavily relies on ground transport which cannot be adopted in U.S.-Europe and U.S.-Asia. In addition, most U.S. manufacturers have outsourced part or all of their production to their OEM partners in Asia. Thus, it is interesting to study the transport modal selection between buyers and suppliers in the U.S.-Asia supply chain.

The three-dimensional panel data are collected at 3-digit NAICS industry level for 21 industries during 2002-2009 for 12 Asian countries. Theoretically there will be 2,016 (=21 industries x 8 years x 12 countries) observations. However, after taking out the trade links without air shipments for that year, this study uses 1,954 observations to estimate the model.

The air share models for import and export are developed as follows. For estimating the models, the OLS (ordinary least square) regression technique is used to generate the base results. Then, the results of a Tobit model adopting the maximum likelihood (MLE) technique are used to compare with the OLS results and test the hypotheses. There are two reasons for using a Tobit model. First, the dependent variables, the import and export air shares, are strictly between 0 and 1. The OLS may generate a negative or greater-than-one predicted value for the dependent variables. In addition, after examining the data distribution (see Figure 3-4), it shows that data distribution is skewed to the right and censored at 0. Using a Tobit model with MLE will avoid the asymptotic bias of OLS and generate more efficient estimation of coefficients (Kennedy, 2003).

Figure 3-4 Histogram of Import and Export Air Shares



The air share models for imports and exports are separately developed as follows. More details about the measurement of each variable are discussed following the estimation models. Some variables have separate numbers for imports and exports. This study uses the numbers for imports for these variables in Model A: Import Air Share Model and attaches an "IM" in front of the variables in the model and the numbers for exports in Model B: Export Air Share Model with an "EX" attached to each variable.

Model A: Import Air Share Model

$IM\ AIRSHARE_{ijt} = a0 + a1\ IM\ TT\_DIFF_{jt} + a2\ IM\ AO\_RATIO_{ijt} + \sum a3_j\ COUNTRY_j$

$+ a4\ IM\ VW\_RATIO_{ijt} + a5\ GM_{it} + a6\ PSURPRISE_{it} + a7\ CAPITAL_{it} + a8\ CVD_{it}$

$+ a9\ SIZE_{it} + a10\ IM\ TIMELINESS_{ijt} + \sum a11_t\ YEAR_t + \square_{ijt}$ (11)

where i=3-digit NAICS industry i, j=Asian origin country j, t = year t during 2002-2009.

Model B: Export Air Share Model

$EX\ AIRSHARE_{ijt} = b0 + b1\ EX\ TT\_DIFF_{jt} + b2\ IM\ AO\_RATIO_{ijt} + \sum b3_j\ COUNTRY_j$

$+ b4\ EX\ VW\_RATIO_{ijt} + b5\ GM_{it} + b6\ PSURPRISE_{it} + b7\ CAPITAL_{it} + b8\ CVD_{it}$

$+ b9\ SIZE_{it} + b10\ EX\ TIMELINESS_{ijt} + \sum b11_t\ YEAR_t + \square_{ijt}$

(12)

where i=3-digit NAICS industry i, j=Asian destination country j, t = year t during 2002-2009.

- AIRSHARE: Air share is collected from U.S. exporters/importers of merchandise database at 3-digit NAICS industry level during 2002-2009 for imports and exports separately. The import air share is calculated by the weight of the U.S. imports through air over the sum of air and ocean imports for 3 digit NAICS industry i in year t. The same approach is applied to export air share.

$$\text{AIRSHARE for Import} = \frac{\text{Import by Air}}{(\text{Import by Air} + \text{Import by Ocean})}$$

- TT_DIFF: This variable, which captures the positive differences between the transit time of air shipping and ocean shipping in term of hours, varies by country and by year. The transit time of air export from the U.S. to country k in year t is calculated by the equation below. The calculation for air import follows the similar approach.

$$\text{Transit Time for Air Export}_{\text{jt}} = (\sum_{k=1}^{m} \sum_{l=1}^{n} d_{lk}^{A} * \frac{f_{lkjt}^{A}}{f_{jt}^{A}}) / 560$$

where d_{lk} represents the mile distance between the U.S. mainland city l (excluding offshore territories like Hawaii, Alaska, and Guam) and the foreign city k of country j in year t and (f_{lkjt}/ f_{jt}) is the percentage of the number of flights from the U.S. city l to the foreign city k of country j in year t over the total number of flights from the U.S. to country j in year t.

The transit time for air shipping in terms of hours is converted from distance by the weighted distance over 560 mph which is the average cruise speed of Boeing 777, while the weighted distance is measured, for import and exports separately, by the product of the share of city-paired flights and its distance. The data of city-pair distance and flight frequency are collected for the U.S. and 12 major Asian trade partners from the T-100 international segment data published by the U.S. Department of Transportation. Based on the same approach, transit time of ocean export is calculated by the equation below. The calculation for ocean import follows the same approach.

$$\text{Transit Time for Ocean Export}_{\text{jt}} = (\sum_{l=1}^{8} d_{lj}^{O} * \frac{f_{ljt}^{O}}{f_{jt}^{O}}) / 17$$

where d_{lj} represents the shortest navigation distance between the U.S. port l and the foreign country j and (f_{ljt}/ f_{jt}) is the percentage of the tons carried by vessels from the U.S. port l to the foreign country j in year t over the total tons carried by vessels from the U.S. to country j in year t.

The transit time for ocean shipping in terms of hours is converted from distance by the weighted distance over the average navigation speed at 17 mph, while the weighted navigational distance is calculated, for imports and exports separately, by the product of the percentage of port-to-country vessel tons and the shortest port-to-country navigational distance. The shortest navigational distance between 8 major U.S. ports (Baltimore, Charleston, Houston, Long Beach, New York, Philadelphia, Norfolk, and Seattle) and 12 Asian trade partners are collected from AtoBviaC Online. Because a large gap in transit time between air and ocean will encourage shippers to use more air due to more savings in transit time, it is expected that TT_DIFF is positively associated with AIRSHARE.

- AORATIO: The ratio is calculated by the air shipping charge per kilogram over ocean shipping charge at the 3-digit NAICS industry level and the country level during 2002-2009. Because shipping charge data is available only for import shipments on the U.S. Importer of Merchandise database, import shipping charge is used as a proxy for the export shipping charge. The shipping charge includes the aggregate cost of all freight, insurance, and other charges excluding U.S. import duties from the carrier at the port of exportation to the carrier at the first port of entry in the U.S. It is found that there are some outliers of extremely low or high value for this variable. To reduce the potential biases from these outliers, this study adopts Winsorization technique which replaces the high extreme values with 99.5 percentiles and low extreme values with 0.5 percentiles (see examples in Chen, et al., 2005, 2007; Han, et al., 2012). Based on the demand rule, higher price leads to lower demand. It is expected that AORATIO is negatively associated with AIRSHARE.

- COUNTRY: This study creates 11 dummy variables for 11 U.S. trade partners while China is the base country. In addition, this study also considers the variables that reflect the regional differences as substitutes for the country dummies. For example, the real interest rate (INTEREST) which is the lending interest rate minus inflation for trade partner j in year t is used to capture the differences in general cost of capital. It is expected that higher cost of capital for the trade partners will increase the demand for faster transportation. The shortcoming of this measure is that it does not take the industry characteristics into account and may not capture the real cost of capital of each industry. The GDP per capita purchasing power parity (GDPPC) for trade partner j in year t captures the income level. It is expected that high-GDP-per-capita countries have more high-income population and better infrastructure, leading to a higher air share in trade. The data of real interest rate and GDP per capita are both collected from EIU country data. The frequency of direct flights (FLIGHT), collected from the U.S. DOT, between the U.S. and the trade partner captures the service availability for air shipping and the size of traffic between the two countries. It is expected that more direct flights between the U.S. and the trade partner lead to a higher air share.
- VW_RATIO: The real value of value-to-weight ratio is measured by the ratio of U.S. total real trade value over total weight for 3-digit NAICS industry i in year t for

imports and exports separately and adjusted by the PPI (producer price index) of the manufacturing industry. The data is collected from U.S. exporters/importers of merchandise database published by the U.S. Census Bureau. The trade value represents the selling price, including inland freight, insurance, and other charges to the port of exportation/importation and excluding international freight and duties. Hypotheses 1a and 1b predict that VWRATIO is positively associated with AIRSHARE.

- GM: Gross margin is a ratio calculated by the difference between shipment value and the summation of direct material costs and direct labor costs over shipment value for the 3-digit NAICS industry i in year t. The required data are collected from the 2002-2009 ASM. Hypotheses 2a and 2b suggest a positive sign for GM on AIRSHARE.
- PSURPRISE: The positive sales surprise captures the portion of unexpected demand higher than forecast. This study, referring to Gaur et al. (2005), measures the positive sales surprise by the following equations.

$$\text{PSURPRISE}_{it} = \frac{\text{Sales}_{it}}{\text{Forecast}_{it}} - 1 \quad \text{if Sales}_{it} > \text{Forecast}_{it}$$
$$\text{PSURPRISE}_{it} = 0 \quad \text{if Sales}_{it} \leq \text{Forecast}_{it}$$

$$\text{Forecast}_{it} = a + b\,(t - 1996), \text{ while a and b are estimated from the Sales}_i \text{ of past five years.}$$

The positive sales surprise is calculated as the percentage of actual sales over forecast, which is predicted by the linear trend of annual sales over the past five years when it is positive. The data is collected from the ASM and calculated at the 3-digit NAICS industry level by year. Hypotheses 3a and 3b predicts a positive sign is expected for

PSURPRISE on AIRSHARE.

- CAPITAL: The cost of capital is measured by the median of weighted average cost of capital in the U.S. using CAPM method for the 3-digit NAICS industry i in year t. The weighted average cost of capital represents the minimum return that a firm has to earn on an existing asset base to satisfy its capital providers. The data is collected from Morningstar.com. Based on Hypotheses 4a and 4b, a positive sign is expected for CAPITAL on AIRSHARE.
- CVD: The coefficient of variations in demand is calculated by the standard deviation over mean of monthly shipment value within one year for 3-digit NAICS industry i in year t. The data is collected from the Manufacturers' Shipments, Inventories, and Orders (M3) survey conducted by the U.S. Census Bureau. Hypothesis 5a and 5b implies a positive sign for CVD on AIRSHARE.
- SIZE: This variable represents the average firm size of top 4 firms for the 3-digit NAICS industry i in year t, taking the concentration rate of an industry into account. The average firm size is calculated by the number of employees in an industry times the market share of top four firms in an industry and divided by four and transformed by logarithm. The data for the number of employees is collected from County Business Patterns (CBP) prepared by the U.S. Census Bureau and the concentration ratio is collected from the 2002 and 2007 Economic Census. The same concentration ratio is applied for two years pre and post census survey. For example, the concentration ratios are the same during 2002 and 2004 and during 2005 and 2009, respectively. This variable captures the firm size of major players rather than the average firm size in an industry to avoid the dilution from many small players.

Hypotheses 6a and 6b predict a negative sign for SIZE on AIRSHARE.

- TIMELINESS: This variable captures the percentage of the shipment value comprised by the parts and components for 3-digit NAICS industry i between U.S. and country j in year t. Referring to Hummels and Schaur (2012), this study identifies the commodity description that includes the key word “part” or “component” which means that they are intermediate inputs of production and relevant to the timeliness in the manufacturing process and calculates their share over the total weight of 3-digit NAICS industry i in year t. It is expected that the industry with more items relevant to the timeliness uses more air shipping and thus a positive sign for TIMELINESS on AIRSHARE.
- YEAR: Year is a dummy variable for year t with the base year of year 2002. The model includes 7 year-dummy variables for year 2003-2009.

Table 3-2 demonstrates the descriptive statistics of the variables used in the models, and Table 3-3 shows the trend of each variable from 2002 to 2009.

Table 3-2 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
EX AIRSHARE	2010	0.139	0.171	0.000	0.985
IM AIRSHARE	2006	0.040	0.075	0.000	0.801
EX TT_DIFF	2010	507	59	385	628
IM TT_DIFF	2010	517	46	424	594
IM AO_RATIO	1954	16.8	23.2	1.2	202.8
GDPPC	2010	15,969	13,874	1,630	43,800
INTEREST	2010	0.039	0.025	-0.073	0.101
EX FLIGHT	2010	5,487	8,792	0	34,759
IM FLIHGT	2010	5,695	8,845	0	34,855
EX VW_RATIO	2010	20.05	52.80	0.0008	562.83
IM VW_RATIO	2006	7.407	13.879	0.0685	141.001
GM	2010	0.395	0.096	0.117	0.622
PSURPRISE	2010	0.049	0.091	0.000	0.580
CAPITAL	2010	0.109	0.022	0.057	0.168
CVD	2010	0.075	0.033	0.020	0.282
SIZE	2010	25,929	29,094	1,340	171,109
EX TIMELINESS	2010	0.094	0.151	0.000	0.982
IM TIMELINESS	2006	0.091	0.151	0.000	0.940

Table 3-3 Trend of Variables during 2002 – 2009

Variable	2002	2003	2004	2005	2006	2007	2008	2009
EX AIRSHARE	0.133	0.132	0.134	0.136	0.142	0.147	0.142	0.145
IM AIRSHARE	0.044	0.039	0.039	0.038	0.039	0.038	0.044	0.041
EX TT_DIFF	527	521	512	497	504	494	493	510
IM TT_DIFF	515	510	509	517	515	515	529	523
IM AO_RATIO	19.4	18.0	16.4	15.0	17.1	16.1	16.6	15.4
GDPPC	12,689	13,357	14,488	15,497	16,788	18,058	18,560	18,306
INTEREST	0.059	0.053	0.037	0.033	0.037	0.043	0.006	0.045
EX FLIGHT	4,988	4,831	5,367	5,740	5,922	5,968	5,827	5,247
IM FLIHGT	5,075	4,979	5,544	6,000	6,195	6,234	6,041	5,487
EX VW_RATIO	19.23	19.97	16.15	20.53	21.33	22.01	20.63	20.53
IM VW_RATIO	7.175	7.087	7.062	7.075	7.223	7.341	7.862	8.437
GM	0.395	0.398	0.399	0.398	0.398	0.395	0.380	0.396
PSURPRISE	0.005	0.014	0.096	0.177	0.078	0.018	0.006	0.000
CAPITAL	0.110	0.097	0.099	0.104	0.104	0.117	0.124	0.116
CVD	0.073	0.069	0.078	0.074	0.074	0.077	0.095	0.062
SIZE	28,986	28,572	28,007	25,572	25,450	24,802	24,395	21,654
EX TIMELINESS	0.095	0.101	0.094	0.093	0.089	0.084	0.084	0.115
IM TIMELINESS	0.093	0.087	0.093	0.089	0.088	0.090	0.095	0.090

*Average across all industries, countries and years

The average air weight share is 13.9% for export, 3.5 times that for import at 4%. There is an upward trend for the air weight share from 13.3% in 2002 to 14.5% in 2009 while a relatively flat trend for imports. The continuous decline in the air shipping rates may provide a good explanation for the increasing trend of air shipping in trade. In 2002, the shipping rate for air was 19.4 times that for ocean. By 2009, this ratio had decreased to 15.4 times. The upward trend of real value-to-weight ratio could be another reason. The real value-to-weight ratio has increased by 6.7% for exports from $19.2/kg in 2002 to $20.5/kg in 2009 and 17.6% for imports from $7.2/kg in 2002 to $8.4/kg in 2009. The economic recession in 2008 has an obvious impact on many variables. For example, the real interest rate and positive sales surprise dropped significantly to near zero in 2008, and demand variations also increase. The cost of capital is on a stable trend fluctuating within a narrow range between 9.7% and 11.7% except for 2008. The percentages of intermediate inputs such as parts and components account for, on average, 9.4% for exports and 9.1% for imports.

Table 3-4 shows the characteristics of each manufacturing industry at the 3-digit NAICS industry level. Computer and electronic product manufacturing has the highest import and export air share at 20.5% and 49.2%, respectively. Apparel manufacturing ranks the second place for the import air share at 12.5% and export at 40.1%. Leather and allied product manufacturing ranks the third place excluding miscellaneous manufacturing. The air shares are usually positively associated with value-to-weight ratio. For example, computer and electronic product manufacturing which heavily relies on air shipping has the highest value-to-weight ratio at $46 for imports and $199 for exports. In addition, petroleum and coal products manufacturing has the highest demand variations and relatively higher positive sales surprise. Transportation equipment manufacturing has the largest average firm size for their top four companies and has the highest percentage of component shipments.

Table 3-5 presents the industry and region characteristics of each Asian country. The column EX AIRSHRE shows the air share from the U.S. to its Asian trade partners, while IM AIRSHARE presents the opposite direction of trade. While Japan and Singapore have higher-than-average shares of air shipping for both imports and exports, Malaysia has a relatively higher share of air shipments from the U.S. In addition, the ratio of air-to-ocean shipping charge shows that air shipping cost is relatively cheap compared with ocean for Japan, Vietnam, Hong Kong, and China. The product value for the imports from Japan and Singapore are significantly higher than that from other countries, which again shows the linkage between air share and product value. In addition, Japan is found to be highly associated with timeliness in terms of the highest share of component shipments for both imports and exports.

Table 3-4 Summary by Industry

	Industry	IM AIRSHARE	EX AIRSHARE	IM AO_RATIO	IM VW_RATIO	EX VW_RATIO	GM	PSURPRISE	CAPITAL	CVD	SIZE	IM TIMELINESS	EX TIMELINESS
311	Food mfg	0.002	0.006	21.258	1.522	0.829	0.363	0.029	0.080	0.047	56,839	0.035	0.008
312	Beverage & tobacco product mfg	0.006	0.022	18.837	1.878	1.087	0.598	0.026	0.067	0.066	15,695	0.008	0.014
313	Textile mills	0.033	0.141	15.376	4.417	6.880	0.317	0.029	0.103	0.070	8,310	0.000	0.000
314	Textile product mills	0.025	0.110	12.869	4.375	5.788	0.354	0.021	0.103	0.071	13,553	0.000	0.000
315	Apparel mfg	0.125	0.401	6.290	15.247	15.657	0.389	0.075	0.104	0.081	7,413	0.030	0.071
316	Leather & allied product mfg	0.109	0.206	7.341	13.112	12.473	0.373	0.133	0.111	0.094	1,838	0.057	0.145
321	Wood product mfg	0.029	0.011	9.307	2.194	0.570	0.282	0.044	0.116	0.095	12,193	0.029	0.161
322	Paper mfg	0.007	0.009	15.409	1.543	0.724	0.385	0.028	0.104	0.034	27,495	0.005	0.000
323	Printing & related support activities	0.030	0.421	13.426	3.476	12.458	0.450	0.030	0.105	0.051	19,867	0.057	0.000
324	Petroleum & coal products mfg	0.009	0.001	68.958	0.551	0.287	0.175	0.126	0.097	0.146	10,890	0.000	0.000
325	Chemical mfg	0.008	0.012	28.045	4.066	1.553	0.489	0.043	0.110	0.053	30,067	0.015	0.000
326	Plastics & rubber products mfg	0.015	0.068	12.141	2.888	5.020	0.376	0.023	0.104	0.063	16,718	0.006	0.007
327	Nonmetallic mineral product mfg	0.009	0.056	36.436	1.001	2.693	0.444	0.039	0.114	0.092	12,560	0.013	0.002
331	Primary metal mfg	0.004	0.081	37.705	1.472	4.055	0.281	0.104	0.140	0.076	23,797	0.001	0.000
332	Fabricated metal product mfg	0.026	0.169	12.398	4.141	10.960	0.407	0.052	0.100	0.063	13,930	0.218	0.145
333	Machinery mfg	0.047	0.140	10.999	8.411	22.293	0.391	0.055	0.134	0.075	38,313	0.354	0.258
334	Computer & electronic product mfg	0.205	0.492	8.845	46.205	198.579	0.535	0.078	0.113	0.106	48,026	0.135	0.244
335	Electrical equipment, appliance, & component mfg	0.049	0.174	9.609	8.644	19.685	0.401	0.064	0.149	0.072	16,568	0.083	0.154
336	Transportation equipment mfg	0.030	0.096	11.078	8.677	36.668	0.308	0.021	0.110	0.114	138,672	0.366	0.329
337	Furniture & related product mfg	0.020	0.059	6.955	3.089	5.263	0.413	0.013	0.111	0.043	14,372	0.186	0.235
339	Miscellaneous mfg	0.053	0.228	11.342	17.921	56.306	0.544	0.012	0.110	0.070	16,453	0.295	0.200
Total		0.040	0.139	16.756	7.407	20.051	0.395	0.049	0.109	0.075	25,929	0.091	0.094

*Average across all countries and years

Table 3-5 Summary by Country

COUNTRY	EX AIRSHARE	IM AIRSHARE	EX TT_DIFF	IM TT_DIFF	IM AO_RATIO	GDPPC	INTEREST	EX FLIGHT	IM FLIHGT	EX VW_RATIO	IM VW_RATIO	EX TIMELINESS	IM TIMELINESS
CHINA	0.100	0.017	481	488	15.820	4,789	0.035	5,331	6,504	13.5	4.1	0.096	0.089
HONG KONG	0.147	0.036	615	566	13.119	36,439	0.054	5,564	5,912	17.3	5.9	0.083	0.085
INDONESIA	0.100	0.019	535	572	19.200	3,218	0.066	116	116	9.8	4.9	0.097	0.076
INDIA	0.143	0.039	542	541	16.607	2,447	0.059	792	793	19.4	8.2	0.100	0.108
JAPAN	0.190	0.090	444	434	11.172	30,810	0.017	31,911	31,852	24.2	12.6	0.137	0.119
S. KOREA	0.143	0.042	438	457	20.866	23,428	0.031	11,217	11,991	23.5	8.8	0.104	0.097
MALAYSIA	0.182	0.030	507	550	17.056	11,873	0.037	0	36	29.7	6.4	0.083	0.084
PHILIPPINES	0.097	0.037	474	513	16.901	2,994	0.042	1,830	1,808	26.7	7.7	0.072	0.071
SINGAPORE	0.187	0.097	572	536	19.366	35,766	0.038	527	521	23.4	15.7	0.076	0.089
THAILAND	0.137	0.029	559	541	18.577	7,032	0.038	262	263	19.4	5.1	0.102	0.062
TAIWAN	0.139	0.028	431	459	20.867	30,095	0.031	8,162	8,401	24.4	5.7	0.078	0.104
VIETNAM	0.098	0.017	487	542	11.294	2,270	0.023	1	1	9.5	3.8	0.102	0.103
TOTAL	0.139	0.040	507	517	16.756	15,969	0.039	5,487	5,695	20.1	7.4	0.094	0.091

*Average across all industries and years

In the correlation table for import-related variables (see Table 3-6) and export-related variables (see Table 3-7), air share has a significantly positive association with value-to-weight ratio, demand variation, gross margin, and the percentage of components. These relationships are consistent with the research hypotheses. The industry of high product value is found to have higher gross margin. In addition, the regional characteristics are highly correlated to each other.

Table 3-6 Correlation Table – Import-related Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. EX AIRSHARE	1.0000												
2. EX TT_DIFF	0.0148	1.0000											
3. IM AO_RATIO	-0.1734*	0.0038	1.0000										
4. GDPPC	0.1361*	0.0509*	-0.0025	1.0000									
5. INTEREST	-0.0263	0.4168*	0.0502*	-0.2027*	1.0000								
6. EX FLIGHT	0.0833*	-0.4775*	-0.0531*	0.4866*	-0.3189*	1.0000							
7. EX VW_RATIO	0.5286*	-0.0286	-0.0944*	0.0479*	-0.0223	0.0311	1.0000						
8. GM	0.2802*	0.0016	-0.1615*	-0.0113	0.0275	-0.0037	0.3107*	1.0000					
9. PSURPRISE	0.0617*	-0.0385	0.0508*	-0.0151	-0.0676*	0.0109	0.0365	-0.1037*	1.0000				
10. CAPITAL	0.1277*	-0.0396	-0.0276	0.0449*	-0.1151*	0.0073	0.0963*	-0.1930*	-0.0065	1.0000			
11. CVD	0.0518*	-0.0231	0.0887*	0.0185	-0.1315*	0.0092	0.1862*	-0.3334*	0.1550*	0.1588*	1.0000		
12. SIZE	-0.0359	0.0094	-0.0459*	-0.0127	0.0206	-0.0025	0.2123*	-0.0813*	-0.0803*	-0.0202	0.1614*	1.0000	
13. EX TIMELINESS	0.2157*	-0.0219	-0.1960*	-0.0030	0.0059	0.0757*	0.2652*	0.0761*	-0.0075	0.2106*	0.1383*	0.3350*	1.0000

* represents p<0.05

Table 3-7 Correlation Table – Export-related Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. IM AIRSHARE	1.0000												
2. IM TT_DIFF	-0.0970*	1.0000											
3. IM AO_RATIO	-0.1890*	-0.0058	1.0000										
4. GDPPC	0.2170*	-0.2952*	-0.0025	1.0000									
5. INTEREST	-0.0620*	0.3286*	0.0502*	-0.2027*	1.0000								
6. IM FLIHGT	0.1724*	-0.7482*	-0.0524*	0.4860*	-0.3217*	1.0000							
7. IM VW_RATIO	0.7785*	-0.0575*	-0.1316*	0.1472*	-0.0324	0.0955*	1.0000						
8. GM	0.1750*	-0.0071	-0.1615*	-0.0113	0.0275	-0.0039	0.2876*	1.0000					
9. PSURPRISE	0.0845*	-0.0279	0.0508*	-0.0151	-0.0676*	0.0126	0.0458*	-0.1037*	1.0000				
10. CAPITAL	0.0883*	0.0469*	-0.0276	0.0449*	-0.1151*	0.0079	0.0894*	-0.1930*	-0.0065	1.0000			
11. CVD	0.1910*	0.0163	0.0887*	0.0185	-0.1315*	0.0094	0.1643*	-0.3334*	0.1550*	0.1588*	1.0000		
12. SIZE	0.0049	-0.0075	-0.0459*	-0.0127	0.0206	-0.0030	0.1121*	-0.0813*	-0.0803*	-0.0202	0.1614*	1.0000	
13. IM TIMELINESS	0.1840*	-0.0522*	-0.1658*	0.0360	-0.0271	0.0666*	0.2207*	0.1192*	-0.0691*	0.1484*	0.0782*	0.4216*	1.0000

* represents p<0.05

3.5 Results and Discussion

Table 3-8 presents the regression results for imports using both OLS and Tobit regression techniques. To begin with, I estimate the import air share model using country and year fixed effects through OLS in the first column and substitute the country dummy variables with three regional-characteristic variables, including the number of direct flights, the GDP per capita, and the real interest rate in the second column. This study repeats the same steps using Tobit regression model in the third and fourth columns. This study does not use industry fixed-effect model because of the concern of multi-collinearity. As discussed earlier, the variables of decision-maker characteristics vary by industry and are considered a more sophisticated form of industry dummies. In the industry fixed-effect model, the variables of decision-market characteristics are the function of industry dummy variables, leading to multi-collinearity. After adding industry dummy variables, the highest scores of VIF (the variance inflation factor) increase from 3.01 in the OLS model to 37.85 for import air share model and from 2.79 to 37.87 for export air share model, showing the existence of multi-collinearity in the model with industry dummies.

The estimation of the air share model for importers shows similar results using OLS and Tobit. Considering that a Tobit model takes the censored data into account, this study uses the results of the fourth column in Table 3-8 to examine the hypotheses for importers. The interpretation of the coefficients in a Tobit model is different from that in OLS. The distribution of the dependent variable in OLS is not constrained, while in a Tobit model it is constrained to be non-negative. Hence, the Tobit estimates must be multiplied by the adjustment factor to make them comparable with OLS estimates (Wooldridge, 2003). In addition, the beta coefficient which is generated by the standardized regression model is usually used to compare the effects of different independent variables on the dependent variable in a multiple regression analysis when the variables are measured in different units. This study uses the beta coefficients to compare the effects of each independent variable on air shares.

For the revenue drivers in the import air share model, the product value is positively associated with import air share at a 0.01 significance level, lending support to H1a. The beta coefficient for the value-to-weight ratio shows that this variable has the strongest effect on the dependent variable. An increase in value-to-weight ratio by one standard deviation leads to an increase in import air share by 0.73 standard deviation. In addition, the gross margin is not found to have any significant impact on the modal choice for importers. Hence, H2a is not supported. A positive sales surprise appears a significant positive effect on the air share for importers at a 0.05 significance level, providing support for H3a. When the importers find that the demand is 10 percent higher than the historical trend, they will increase the share of air shipping by 0.34 percent point for imports.

For the cost drivers, there is no evidence showing that the cost of capital has an impact on modal choice for importers, and H4a is not supported. The demand variation is found to be positively associated with the import air share at a 0.01 significance level, lending support to H5a. It implies that an importer in an industry with high month-to-month demand fluctuations tends to use more air shipping to quickly respond to the demand. Furthermore, this study finds that when the average firm size of the top four players is large, this industry tends to use more ocean shipping and less air shipping. This finding supports the H6a and provides some evidence that big firms may better leverage their economies of scale and use the risk pooling technique to aggregate demand and lower demand variation. In addition, when an industry is dominated by a few big firms, they have strong bargaining power to force their downstream customers to follow their replenishment schedule. Hence, they may not use faster transportation when there is more demand than expected. Next to product value and the shipping charge, the firm size is the third strongest variable in terms of importance of effect on air share.

Table 3-8 Estimation Result for Imports

	(1)		(2)		(3)			(4)		
VARIABLES	OLS		OLS		Tobit			Tobit		
	Coefficient	beta	Coefficient	beta	Coefficient	Marginal Effect	beta	Coefficient	Marginal Effect	beta
IM TT_DIFF ('000)	0.0506	0.03	0.0877**	0.05	0.0587	0.0482	0.04	0.0895**	0.073	0.05
	(0.63)		(2.47)		(0.73)			(2.48)		
IM AO_RATIO ('000)	-0.3055***	-0.09	-0.2963***	-0.09	-0.4956***	-0.4067	-0.15	-0.4817***	-0.3933	-0.15
	(-6.88)		(-6.60)		(-9.24)			(-8.94)		
IM FLIGHT ('000,000)			0.691***	0.08				0.717***	0.5850	0.08
			(3.68)					(3.77)		
GDPPC ('000,000)			0.449***	0.08				0.462***	0.377	0.08
			(5.32)					(5.41)		
INTEREST			-0.0875	-0.03				-0.0889	-0.0726	-0.03
			(-1.52)					(-1.52)		
IM VW_RATIO	0.0039***	0.72	0.0040***	0.74	0.0038***	0.0031	0.70	0.0040***	0.0032	0.73
	(46.74)		(49.07)		(45.97)			(48.26)		
GM	-0.0191	-0.02	-0.0276**	-0.03	-0.0066	-0.0054	-0.01	-0.0157	-0.0128	-0.02
	(-1.50)		(-2.14)		(-0.50)			(-1.19)		
PSURPRISE	0.0462***	0.05	0.0428***	0.05	0.0450***	0.0369	0.05	0.0411**	0.0336	0.05
	(2.94)		(2.68)		(2.80)			(2.52)		
CAPITAL	-0.0230	-0.01	-0.0284	-0.01	0.0592	0.0486	0.02	0.0546	0.0446	0.02
	(-0.43)		(-0.53)		(1.09)			(0.99)		
CVD	0.1669***	0.07	0.1506***	0.06	0.1554***	0.1276	0.06	0.1380***	0.1127	0.06
	(4.48)		(3.99)		(4.07)			(3.56)		
SIZE	-0.0131***	-0.15	-0.0131***	-0.15	-0.0130***	-0.0107	-0.15	-0.0131***	-0.0107	-0.15
	(-10.77)		(-10.67)		(-10.61)			(-10.50)		
IM TIMELINESS	0.0263***	0.05	0.0241***	0.05	0.0245***	0.0201	0.05	0.0222***	0.0181	0.04
	(3.65)		(3.30)		(3.37)			(3.01)		
Constant	0.1112***		0.1026***		0.0962**			0.0904***		
	(2.65)		(4.35)		(2.26)			(3.77)		
YEAR	Included		Included		Included			Included		
Country	Included		Not Included		Included			Not Included		
Industry	Not Included		Not Included		Not Included			Not Included		
Observations	1,954		1,954		1,954			1,954		
R-squared or Pseudo R-squared for Tobit	0.673		0.661		-0.5137			-0.4978		

Dependent varilable is import air weight share; t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Most control variables show the expected signs. For the modal characteristics, a large gap between the transit time of air and ocean shipping leads to more import air share at a 0.05 significance level. A higher air shipping charge over ocean is associated with a lower share of air shipping in trade at a 0.01 significance level. These findings are consistent with economic theory and the FTD literature. The shipping charge is the factor that has the second strongest effect on the air share. For the regional characteristics, the size of air traffic measured by the frequency of inbound direct flights is positively associated with import air share. It implies more direct flights between the U.S. and its trade partners could facilitate firms to use more air shipping in trade. From 1992, the U.S. government has been advocating the open skies policy, leading to an increase in the number of direct flights linking to the U.S. This may have caused substantial changes in firms' transport modal decisions. The imports associated with the countries of high GDP per capita is related to higher air share at a 0.01 significance level. Because the manufacturers in a high-income country, such as Japan, own more patents than those in low-income countries, they export more critical components or high-technology products to the U.S. through air. The real interest rate represents the general level of cost of capital in a country. There is no evidence showing that the real interest rate at the exporter's country is associated with the modal selection. For the shipment characteristics, this study replicates the finding of Hummels and Schaur (2012) by showing that the percentage of component shipments is positively associated with air share. It implies that air shipping plays an import role in the timeliness of supply chains.

Furthermore, the estimation results for air share model for exports are presented in Table 3-9. The OLS technique generates very similar result to the Tobit model. This study uses the last column which includes the year fixed effect and regional characteristics, rather than country fixed-effect, and uses the Tobit model to examine the hypotheses. For the revenue drivers, value-to-weight ratio has the strongest effect on the air share, but the magnitude is weaker than that on the import air share. An increase in value-to-weight ratio by one standard deviation leads to a higher export air share by 0.49 standard deviation at a 0.01 significance level, lending support to H1b. Unlike importers, exporters in high-gross-margin industries use more air shipping at a 0.01 significance level. A higher gross margin by 10 percent points leads to a higher air share by 2.4 percentage points, providing support to H2b. Moreover, next to product value and firm size, gross margin has the strongest effect on export air share. In addition, the positive sales surprise does not show a significant effect on exporter's air share, failing to support H3b. It implies that the exceptional increase in sales does not facilitate exporters to use faster transportation.

The signs of coefficients for the control variables in the export air share model are as expected and similar to those for imports. For the modal characteristics for exports, the gap in transit time has a positive effect on export air share. Subject to data availability, this study uses import shipping charges as a proxy for export shipping rates. The results show that the ratio of import air-to-ocean shipping charges is negatively associated with export air share as expected. For the regional characteristics, only the GDP per capita appears to have a significantly positive relationship with export air share. It is likely because the importing countries of high income level have a higher valuation on time and the exporters prefer to meet their demand as early a possible. For the shipment characteristics, the industries with more intermediate input for production use more air shipping at a 0.01 significance level. The concern for timeliness is one of the major reason for using air, and it also implies that air shipping may facilitate cross-border JIT (just in time) system.

Table 3-9 Estimation Result for Exports

VARIABLES	(1) OLS		(2) OLS		(3) Tobit			(4) Tobit		
	Coefficient	beta	Coefficient	beta	Coefficient	Marginal Effect	beta	Coefficient	Marginal Effect	beta
EX TT_DIFF ('000)	-0.1277	-0.04	0.1363*	0.05	-0.1058	-0.0905	-0.04	0.1360*	0.116	0.05
	(-0.66)		(1.96)		(-0.55)			(1.96)		
IM AO_RATIO ('000)	-0.6106***	-0.08	-0.6017***	-0.08	-0.6590***	-0.5639	-0.09	-0.6473***	-0.5521	-0.09
	(-4.41)		(-4.34)		(-4.70)			(-4.59)		
EX FLIGHT ('000,000)			0.54	0.03				0.541	0.4610	0.03
			(1.08)					(1.08)		
GDPPC ('000,000)			1.17***	0.09				1.170***	0.997	0.09
			(4.12)					(4.12)		
INTEREST			-0.0064	0.00				-0.0151	-0.0129	0.00
			(-0.04)					(-0.09)		
EX VW_RATIO	0.0016***	0.49	0.0016***	0.50	0.0016***	0.0013	0.49	0.0016***	0.0014	0.50
	(23.08)		(23.42)		(23.03)			(23.34)		
GM	0.2663***	0.14	0.2553***	0.13	0.2763***	0.2364	0.14	0.2657***	0.2266	0.14
	(6.65)		(6.33)		(6.90)			(6.57)		
PSURPRISE	0.0926*	0.05	0.0908*	0.05	0.0906*	0.0775	0.05	0.0885*	0.0755	0.05
	(1.90)		(1.84)		(1.86)			(1.79)		
CAPITAL	0.6302***	0.08	0.6271***	0.08	0.6642***	0.5683	0.08	0.6616***	0.5643	0.08
	(3.79)		(3.73)		(4.00)			(3.94)		
CVD	-0.1218	-0.02	-0.1395	-0.02	-0.1153	-0.0987	-0.02	-0.1338	-0.1141	-0.02
	(-1.03)		(-1.17)		(-0.98)			(-1.12)		
SIZE	-0.0452***	-0.23	-0.0456***	-0.24	-0.0448***	-0.0383	-0.23	-0.0452***	-0.0386	-0.23
	(-12.07)		(-12.09)		(-12.00)			(-12.00)		
EX TIMELINESS	0.0920***	0.08	0.0954***	0.08	0.0912***	0.0780	0.08	0.0946***	0.0807	0.08
	(4.13)		(4.25)		(4.11)			(4.23)		
Constant	0.4211***		0.3084***		0.3979***			0.2968***		
	(3.88)		(5.17)		(3.67)			(4.97)		
YEAR	Included		Included		Included			Included		
Country	Included		Not Included		Included			Not Included		
Industry	Not Included		Not Included		Not Included			Not Included		
Observations	1,954		1,954		1,954			1,954		
R-squared or Pseudo R-squared for Tobit	0.395		0.381		-0.7552			-0.7217		

Dependent varilable is export air weight share; t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results for imports and exports show important insights (see Table 3-10). Comparing and contrasting the results reveals some interesting differences between the decision maker characteristics of importers and exporters. Importers and exporters both take the product value and the characteristics of mode and shipment into account. However, the importers in the U.S. pay more attention to the dynamics of demand and tend to use faster transportation to realize the demand surge as early as possible. In addition, higher frequency of direct flights encourages the U.S. importers to use more air shipping to fulfill their demand. Because the importers are more sensitive to air shipping charges than exporters, more competition in the air cargo market also facilitates more use of air shipping. Furthermore, the insignificant coefficients for gross margin and cost of capital imply that the importers put more weight on demand characteristics. Despite the finding that both importers and exporters use more air shipping when there is a positive sales surprise, the modal decision of exporters is less determined by the demand variation. Instead, U.S. exporters make modal decisions considering the working capital and gross margin more than U.S. importers. It seems that the exporters may tend to more highly value the profit contributed by the shipments and the cash cycle benefit brought by air shipping when making the transport modal decision.

Table 3-10 Summary of Estimation Results

CATEGORY	VARIABLE	U.S. IMPORTER			U.S. EXPORTER		
		Beta	Sig.	Hypothesis*	Beta	Sig.	Hypothesis*
INDUSTRY	VW_RATIO	.73	***	H1a S	.50	***	H1b S
	GM	-.02		H2a NS	.14	***	H2b S
	PSURPRISE	.05	**	H3a S	.05	*	H3b S
	CAPITAL	.02		H4a NS	.08	***	H4b S
	CVD	.06	***	H5a S	-.02		H5b NS
	SIZE	-.15	***	H6a S	-.23	***	H6b S
MODE	TT_DIFF	.05	**		.05	*	
	AO_RATIO	-.15	***		-.09	***	
REGIONAL	FLIGHT	.08	***		.03		
	GDPPC	.08	***		.09	***	
	INTEREST	-.03			.00		
SHIPMENT	TIMELINESS	.04	***		.08	***	

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

The results show some opportunities of profit maximization for both importers and exporters. For U.S. importers, it seems that U.S. importers pay more attention to demand uncertainties when choosing mode. It is suggested that they could take both gross margins and cost of capital into consideration. For the products with high gross margins, importers could consider using a faster transport mode to realize demand and minimize the sales loss from unmet demand. In addition, it is suggested that importers could consider using more air shipping to relax their demand for working capital when their cost of capital is high. For U.S. exporters, firms traditionally believe that a higher inventory level is required when demand variation is high. However, using faster transport mode to manage demand uncertainties at a lower inventory level could be another option.

3.6 Conclusion

Though the air shipping charge is several times that of ocean shipping, the proportion of air shipping in international trade has been rising significantly in the past four decades. Using the trade data and the survey data of U.S. manufacturers, this study examines the factors that affect the decision of transport modal choice for imports and exports. Given that the literature identifies three main categories of variables that affect modal decision including the characteristics of mode, shipment, and region, this study, based on economic theory, proposes that the industry characteristics which consist of revenue drivers and cost drivers have an impact of modal decision. The results show that both importers and exporters use more air shipping for high-value products and when there is a positive sales surprise. Large importers and exporters have a smaller proportion of air shipping compared with small ones. While an importer’s modal decision is highly associated with demand dynamics, an exporter’s decision is more determined by gross margin and cost of capital but less by demand variation.

This study contributes to the literature and practioners. Academically, the previous studies consider the characteristics of mode, shipment, and region in the transport model selection. However, few studies consider the revenue and cost drivers that compose the decision maker's profit in the modal decision. This study fills the gap in the FTD literature by including the profit-related factors in the model of transport modal selection. Second, most FTD studies focus on the modal split between truck and rail in a domestic market. As globalization increases the demand for international transport in global supply chains, it is important to examine the factors that affect the modal choices in an international context. This study is among the early papers that studies the modal decision in an international context. For practioners, this study develops a framework that selects transport mode from the perspective of profit maximization rather than just cost minimization or revenue maximization. It could inspire practioners to consider the transport modal decision from a more comprehensive angle. In addition, the practical suggestions are made to both importers and exporters.

There exist some research limitations as well as the opportunities for future research. First, this study uses aggregate data to estimate modal choice. As indicated in the literature review section, the disaggregate research is more precise and provides richer information about the decision maker's behaviors. The future research could collect the firm-level data to examine how the revenue and cost drivers affect their modal decisions. In addition, this study uses only U.S. manufacturer's data for research and covers only the supply chain activities related to manufacturers. However, the wholesalers and retailers may have different decision behaviors. Furthermore, the transportation links both sellers and buyers in a supply chain, and the modal decision will have an impact on both parties. From a systematic view, the right choice of transport mode may increase the profits of both parties. For example, air shipping which features short transit time and more frequency may decrease the bullwhip effects and lower inventory levels of both parties. The supply chain members could collaborate on the joint modal decision to maximize the overall supply chain profits.

Chapter 4 Essay Two: A Study on Transport Modal Selection and Manufacturing Inventory Levels in Global Supply Chains

4.1 Introduction

Globalization is among the most important factors that affect firms' operations and supply chain management in the late 20th century and early 21st century. As emerging economies in Asia like China, India, and Vietnam become the factories of the world, firms have managed to design their supply chains in a global perspective, which has, to a certain extent, driven down the production costs, increased the access to global markets, and responded to market demand more efficiently (Han et al., 2008).

However, despite the advantages above, globalization leads to longer supply chains due to the increased number of supply chain members involved and wider geographic coverage, leading to longer lead times, more demand variation, and higher risks of supply chain disruption. These factors may have contributed to the expansion of the bullwhip effects and thus more inventories for manufacturers. Before going global, firms source their raw materials and components from local suppliers and sell finished goods in domestic market. After expanding the supply chain to the global market, firms begin to source from oversea suppliers and also increase their material inventories as buffers to mitigate the risk of longer and more variable lead times (Han et al., 2008). In addition, when firms sell more products to oversea customers, they keep a higher inventory level of finished-goods due to lower shipping frequency and longer lead time (Levy, 1997; Rajagopalan and Malhortra, 2001; Han et al., 2008). As a result, the longer lead time prolongs the inventory days, contributing to a longer cash conversion cycle. It takes firms a longer time to collect cash from customers and thus requires more working capital. Hence, how to increase inventory turnover and reduce inventory days becomes an increasingly important issue in the era of globalization.

The use of air shipping (which features more frequency and shorter transit time with smaller batch sizes compared with ocean shipping in international transportation) in shipment delivery may enable manufacturers to respond to demand more efficiently, decrease the bullwhip effect in supply chains, and keep lower inventory levels. The experience in the U.S. domestic market could be replicated in global supply chain. Because of the deregulations of air and ground transportation in the 1970's, more transportation modal choices and customized air-truck service facilitated the implementation of the just-in-time (JIT) system in the U.S. in the 1980's (Bagchi et al., 1987; Daugherty and Spencer, 1990; Larson, 1998). In addition, the adoption of JIT is found to be associated with higher ton-mile shares of air cargo in the U.S. domestic freight market (Larson, 1998). Firms committed to JIT claim that they are using more air shipping and truck services and less rail transportation (Lieb and Miller, 1988; Harper and Goodner, 1990). That is, the mode with shorter transportation time and higher flexibility becomes more attractive when firms pursue low inventory levels and on-time performance. As globalization leads to higher inventory levels in the global supply chain, it may facilitate manufacturers' use of more air shipping so as to decrease the bullwhip effect and lower inventory levels.

The objective of this study is to empirically examine the effects of transportation modal selection on the manufacturer's inventory levels in global supply chains. We ask two research questions. To what extent does more usage of air transport in trade lead to lower manufacturing inventory levels? In addition, what factors determine a firm's selection of transportation mode in global supply chains? Using the trade data and inventory data at a 6-digit 2002 NAICS (North American Industry Classification System) level for the manufacturing industry during 2002-2009, the study develops econometric models to examine the effects of air shipping in trade on manufacturing inventory levels and the determinants of transportation modal selection.

This study makes contributions to both the research literature and to practitioner knowledge. Academically, this study is, to our knowledge, the first empirical paper that quantifies the effect of transportation mode on inventory levels, filling a gap in the literature of inventory study. For practitioners, this study offers different decision guidelines for modal split based on the concepts of total cost minimization and profit maximization and reiterates the importance of the latter.

The rest of the paper is structured as follows: Section 2 reviews the literature and develops research hypotheses. Section 3 describes our research setting, data, variables and econometric models. Section 4 presents the results. Section 5 discusses our results and presents an extended analysis of our findings. Finally, Section 6 concludes our analysis and discusses limitations and potential future research.

4.2 Literature Review and Hypotheses Development

In this section, the causes of the bullwhip effect are explored. In addition, this section examines how globalization could have contributed to increased bullwhip effect and higher inventories in manufacturing industries. It is proposed that the increased use of air shipping in international trade may decrease the bullwhip effect and thus lower manufacturers' inventory levels. In addition, to control for other factors that affect inventory levels, the literature about inventory theories and studies is reviewed. Moreover, this study proposes a conceptual framework that explains the factors determining the modal selection in global supply chains.

4.2.1 Bullwhip Effect and Globalization

The bullwhip effect describes a phenomenon where the variation of demand orders is amplified as it moves up the supply chain (Lee et al. 1997a, 1997b). For example, Procter & Gamble (P&G) found much larger variations in the distributor's orders given that the variation in retailer's sales is not excessive. Consequences of the bullwhip effect are that supply chain members, especially those in the upstream, have to carry unnecessary inventories and spend additional operational costs to deal with the fluctuations in demand. Lee et al. (1997a, 1997b) indicate that demand forecasting updates, order batching, price fluctuations, and rationing and shortage gaming cause a distortion of demand information, leading to the bullwhip effect. First, the distortion of demand information occurs when firms develop demand forecasting based on the order history (which does not reflect the true demand) from their immediate customers. Such distortion will be further amplified when replenishment lead time is long and when the number of supply chain members increase. Second, firms may consolidate demand and place orders in a large batch to save ordering cost and take advantage of economies of scale, leading to distorted demand information. Third, the fluctuations in prices and promotional discounts provide firms with incentives to buy in advance and causes firms to stop buying for a long period until they deplete inventories. Fourth, when there is more demand than supply and a manufacturer rations supply to its customers, downstream customers may exaggerate their orders in order to get the amount they really need.

When a firm expands its supply chain to global markets, the distortion of demand information may further increase due to the following reasons. First, as the lead time between order placement and receipt becomes longer in global supply chains, it becomes more challenging for retailers to make accurate demand forecasts (Nahmias, 1997). The literature indicates that the increase in the order variation from the retailer to the manufacturer is an increasing function of the lead time (Lee et al., 1997a; Chen et al., 2000). That is, the longer lead time leads to a larger batch size and hence larger variations in orders. As a result, the variations in orders are amplified in global supply chains.

Second, in global supply chains, firms rely heavily on ocean transport, which has much larger capacity than trucks, leading to larger batch sizes. In addition, compared with domestic shipping, global shipping has less departure frequency, resulting in less order frequency and larger batch sizes. These factors contribute to longer bullwhip effects in global supply chains.

Third, in global supply chains, the longer supply chain increases the risk of supply chain disruption and shipment delays. For example, natural factors like tsunamis, typhoons, and earthquakes, and man-made factors like terrorist attacks, port strikes, and customs delays contribute to potential supply disruptions. To mitigate the risks of supply shortage, retailers may keep a higher inventory level, leading to inflated orders.

As a result, in response to the increased bullwhip effect in global supply chains, manufacturing firms have increased their inventory levels. Han et al. (2008) find that a 10 percentage-point increase in the export-to-sales ratio is associated with a 2.05-day or $1.4 billion increase in finished goods inventories.

4.2.2 Air Shipping and JIT in the U.S.

The JIT (just-in-time) philosophy became popular in the U.S. during the late 1970s and 1980s. The JIT philosophy which features the elimination of waste and unevenness in operations is originally from the Toyota production system and the work of Taiichi Ohno (1988). Considering the costs of capital and warehouse space and the irresponsiveness to customer needs resulting from large batches of production and high inventories, Ohno advocates small batches of production and lower inventory levels. It has been shown that JIT can effectively eliminate inventories and enhance manufacturing efficiency and responsiveness to market demand (Ohno, 1988; Harper and Goodner, 1990).

The deregulation of air transport in 1977 has contributed to the success of JIT implementation in the U.S. (Bagchi et al., 1987; Daugherty and Spencer, 1990; Larson, 1998). The amendments to the Federal Aviation Act in 1977 and the passage of the Airline Deregulation Act of 1978 removed government's control over routes and rates, significantly lowering the air shipping rates and facilitating the carrier's offering of customized and contractual air-truck services to shippers (Daugherty and Spencer, 1990; Larson, 1998). Similar deregulation occurred in surface transportation as well in the late 1970's. As a result, the deregulation in air transport and surface transportation in the 1970's offered more transportation modal choices to firms and facilitated the implementation of the JIT system in the U.S. in the 1980's (Bagchi et al., 1987; Daugherty and Spencer, 1990; Larson, 1998).   In addition, the adoption of JIT is found to be associated with a higher ton-mile share of air cargo in the U.S. domestic freight market (Larson, 1998). Firms committed to JIT claim that they are using more air cargo and truck services and less rail transportation (Lieb and Miller, 1988; Harper and Goodner, 1990).

4.2.3 *Air Shipping in Global Supply Chains*

When a firm expands its sales to global markets, it encounters the decision of selecting transportation mode for international shipping. Unlike domestic shipping which mainly consists of truck and rail, international shipping heavily relies on air and ocean transport. Compared with ocean transport, air transport features much shorter transit time, more departure frequency, smaller capacity, and higher unit transportation costs. Because of these characteristics, the shift from ocean to air transport in international shipping may contribute to a decrease in the bullwhip effect in global supply chains. The reasons are explained below.

First, Nahmias (1997) indicates that the longer forecast horizon makes accurate forecasting more challenging. Shorter transportation lead times lead to more accurate demand forecasts. For ocean shipping, it usually takes more than one month from order placement to shipment delivery. If a retailer shifts from ocean to air shipping (which takes less than one week), a retailer can make more accurate forecasts for demand in one week compared with ocean shipping's one month. Hence, a retailer could do a better job of forecasting and place an order with smaller deviation from the actual demand, contributing to a smaller bullwhip effect. In a case study, Levy (1997) finds that the noticeable savings in transit time, lower inventories and more accurate sales forecasting make air transport a more appealing option in international shipping, especially for high-end products shipped from remote countries.

In addition, Lee et al. (1997a) and Chen et al. (2000) indicate that the variation of orders from the retailer to the manufacturer is an increasing function of the lead time as shown below. With a shorter replenishment lead time, the variations in the orders from retailers to manufacturers will be lower as well. Thus, the bullwhip effect is decreased and manufacturers could keep a lower level of safety stock for finished goods.

Moreover, in-transit inventory is a function of transit time and lot size. Because ocean shipping takes longer and has a much larger lot size compared with air shipping, the in-transit inventory on average for ocean shipping is much more than that for air shipping. It is expected that the industry with a higher air shipping share has a lower inventory levels of finished goods as a result of lower in-transit inventory.

Based on the arguments above, Hypotheses 1a is developed as follows.

H1a: For manufacturers, a higher air share in export is negatively associated with the inventory days of finished goods.

In addition, it is very likely the effect on inventory reduction from higher air shipping share could be diminishing as air share goes up. When a manufacturing firm increases its air share by 20 percent points from 10 percent to 30 percent, it may involve transformations in operational processes such as converting from mass production to small-batch production, leading to an obvious reduction in inventory days. When air share increases from 30 percent to 50 percent, the effect on inventory reduction may remain but at a diminishing rate because it involves less operational transformation but the savings from reduced in-transit inventories. Hypothesis 1b is developed as follows.

H1b: Air shipping reduces finished-goods inventories at a decreasing rate.

4.2.4 Inventory Studies

To control for other factors affecting inventory levels, this study surveys the literature about empirical inventory studies and summarized as follows. More details are included in Chapter 2. For the overall trend of inventory in the U.S., Rajagopalan and

Malhotra (2001) study trends in inventory ratios and find that total manufacturing inventory ratios appear to show a decreasing trend, with materials and WIP inventory ratios demonstrating greater decreases than finished goods inventory ratios in most industry sectors. Chen et al. (2005), using firm-level data from COMPUSTAT, examine the effect of inventory days on financial performance from 1981 to 2000 and find that firms experienced declines in inventory-days, on average, by about 2% during the research period, with WIP inventory-days showing the largest decline at 6%, followed by raw materials at 3%. Chen et al. (2007) collect both firm-level data from COMPUSTAT and aggregate-level sales and inventory data from the U.S. Census Bureau for manufacturing, retail and wholesale sectors and compare the inventory patterns from these two sources. They find that wholesale inventory days dropped significantly from 1981 to 2004, while retail inventory did not decline until 1995, controlling for the same variables as those used by Chen et al. (2005).

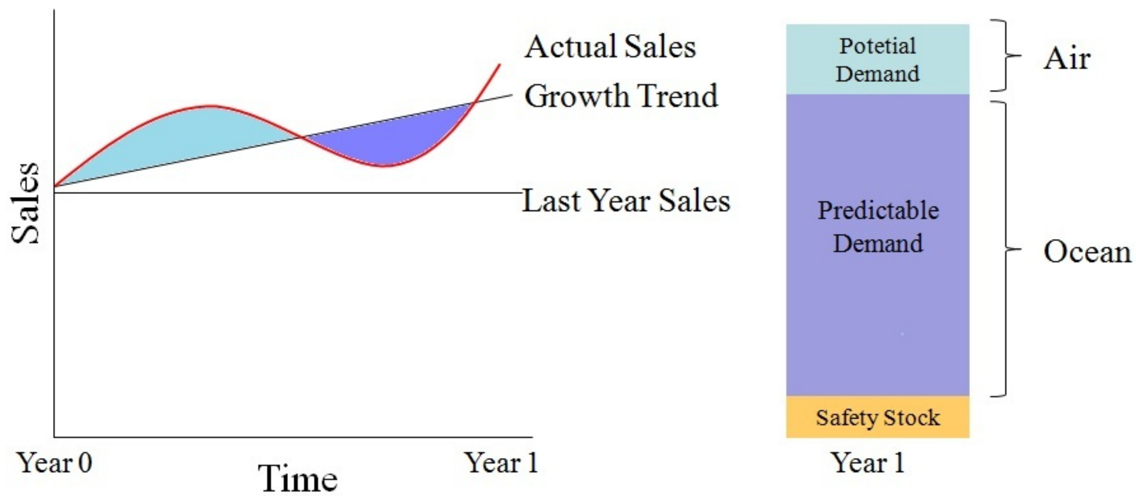
For the effects of specific factors on inventory performance, Gaur et al. (2005) use firm-level financial data to examine how gross margin, capital intensity, and the ratio of actual sales to expected sales respond to inventory turnover. Their results show that lower inventory turnover is associated with higher gross margin, lower capital investment, and a lower ratio of actual sales to expected sales. Shah and Shin (2007) use sector-level data from the Bureau of Economic Analysis (BEA) from 1960 to 1999 and find that information technology (IT) investment contributes to improved financial performance through its impact on the inventory-to-sales ratio. Rumyantsev and Netessine (2007) use the quarterly data of U.S. listed companies to test the hypotheses derived from classical inventory models. They find support for positive relationships between inventory turnover and demand uncertainty, length of lead times, and gross margins, and a negative relationship with firm size at the firm level and the results hold at the aggregate industry level. Han et al. (2008) study the effects of import ratios and export ratios on inventory days of raw material and finished goods, respectively while controlling for cost of capital, sector inflation, sector real growth, and the ratio of IT investment.

4.2.5 Determinants of Transport Modal Selection in Global Supply Chains

Transportation, which offers firms the utilities of time and place, links up operations and sales. Therefore, the transport mode has an impact on both costs and revenues of a firm. The decision of transport modal selection is based on the maximization of profit. In pursuit of profit maximization, firms pursue two strategies separately or simultaneously: revenue maximization and cost minimization. The transport modal selection could be driven by the revenue maximization strategy or/and the cost minimization strategy.

To explain the revenue and cost drivers contributing to the decision of a transport mode, this study proposes a conceptual framework as shown in Figure 4-1. It is a common practice that a firm develops its demand forecast toward next period in order to prepare the production and distribution plans. Using the historical trend as a baseline, demand below trend is relatively predictable. Because of its predictability and the cost concern, a firm could reserve ocean shipping capacity close to the historical trend and include the lead time of ocean shipping in the development of its master production schedule. For the demand above trend, it is potential demand and relatively uncertain. Once the actual demand grows over the historical trend, a firm usually has a shorter lead time to fulfill the unplanned demand and needs to respond quickly. Hence, it may use faster transportation such as air shipping to realize the demand surge. Based on this framework, the factors that may determine a firm's transportation modal selection in global supply chains are discussed below.

Figure 4-1 Classification of Demand Based on Uncertainty



First, a positive sales surprise, which is the demand above the historical trend, may facilitate a firm's decision to use more air shipping. As argued above, a firm may use ocean shipping to deal with certain demand and air shipping for potential demand. The portion of demand over trend represents the potential demand, and a firm cannot use prescheduled ocean shipping to realize the demand. Hence, it is hypothesized that firms use more air shipping when there are positive sales surprises. Hypothesis 2 is developed as follows.

H2: For manufacturers, the use of air shipping in exports is positively associated with a positive sales surprise.

Second, a firm facing high demand variation may tend to use more air shipping. High demand variation implies a large portion of demand is uncertain. Using faster transportation, such as air shipping, enables a firm to quickly respond to unexpected demand surges and prevent stockouts. Inventory theory indicates that safety stock is a function of the service level and the demand variation during lead time, which is a function of the length of lead times, the size of demand, and the variations in lead time and demand (Tersine, 1994). When demand variation increases, more safety stock must be kept to achieve 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 a firm can keep a lower inventory level at the same level of service. Hummels and Schaurs (2010) find that higher price volatility, measured by the coefficient of variation in product values in a year, is associated with more usage of air shipping in imports. In this study, it is hypothesized that firms in an industry with high demand variation tend to use more air shipping. Hypothesis 3 is developed as follows.

H3: For manufacturers, the use of air shipping in exports is positively associated with demand variation.

Larger firms may tend to use less air shipping and more ocean shipping because of risk pooling. Because large firms have relatively larger customer bases, the variation in demand at different locations may cancel out each other when demand is aggregated across different locations. Rumyantsev and Netessine (2007) indicate that larger firms keep lower inventory levels due to lower aggregate demand variation by risk pooling. Similarly, larger firms may take advantage of risk pooling to lower demand variation and increase the predictability of demand. Thus, larger firms may have a higher share of ocean shipping. In addition, larger firms have higher bargaining power over their customers. Hence, they could be able to negotiate a more favorable contract with a later delivery date. Hypothesis 4 is developed as follows.

H4: For manufacturers, the share of air shipping in exports is negatively associated with their firm size.

For products with high gross margins, firms may use more air shipping for the following reasons. First, though the cost of air shipping is much higher compared with that of ocean shipping, it accounts for a smaller portion for high gross-margin products after controlling for the value of product, making air shipping more affordable. Moreover, high gross margin implies higher losses from unmet demand, offering firms more incentive to realize demand through faster transportation. Hence, it is hypothesized that firms in an industry with high gross margins will use more air shipping. Hypothesis 5 is developed as follows.

H5: For manufacturers, the share of air shipping in exports is positively associated with their gross margins.

Furthermore, when firms are sensitive to time, they may tend to use faster transportation mode to shorten the lead time. There are at least two drivers that increase firms' sensitivity to time. First, if firms have a higher cost of capital, they tend to use more air shipping. The cash-to-cash cycle, which is calculated as inventory days plus account receivable days minus account payable days, is a measure of the requirement for working capital. 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 well as the cost of capital. Thus, they may use faster transportation to shorten inventory days. Hypothesis 6 is developed as follows.

H6: For manufacturers, the share of air shipping in exports is positively associated with their cost of capital.

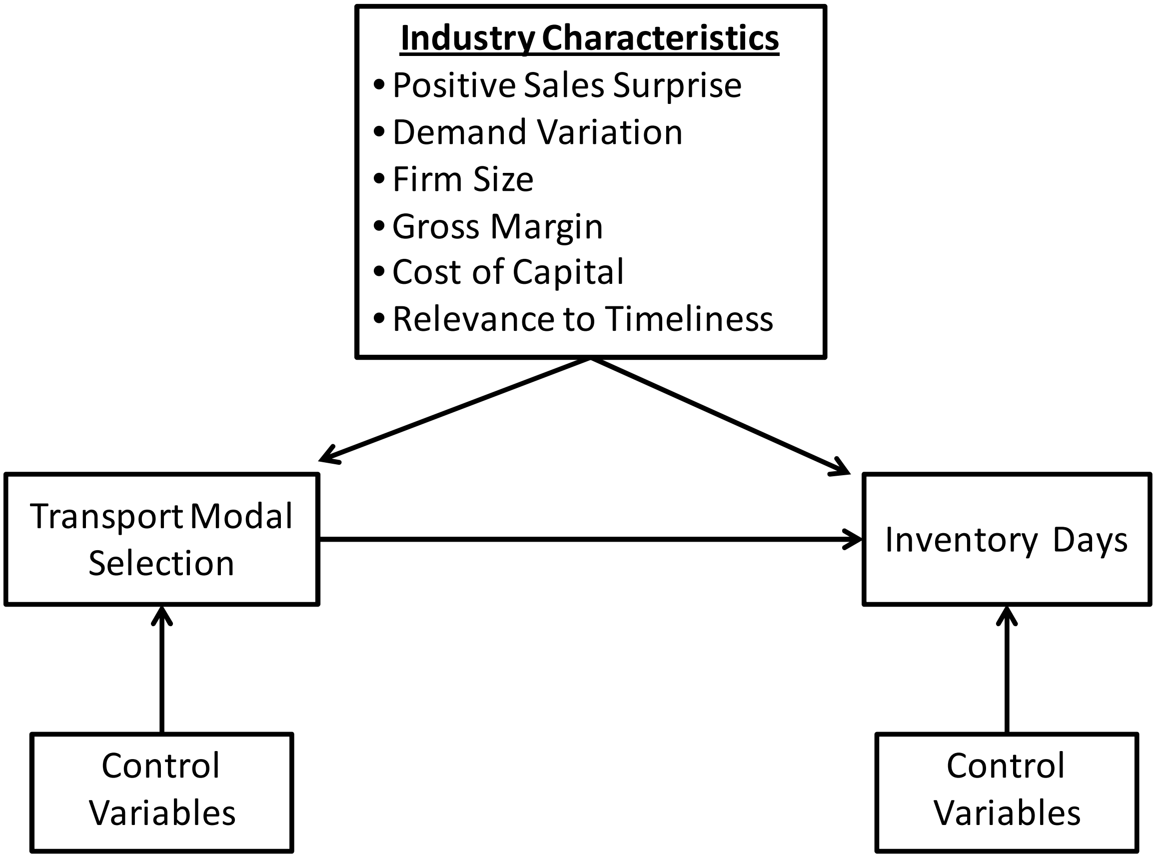
In addition, if the products are related to timeliness, firms may use more air shipping. For example, if an exporter's product is a component which is an intermediate input of the downstream product, poor on-time performance may lead to a shutdown in the manufacturing process. Hence, the downstream customers will be willing to pay more to get the shipments on time. Hummels and Schaur (2010) find that the commodities which contain parts or components are associated with a higher air share in imports. This study tests this hypothesis for exports. Hypothesis 7 is developed as follows.

H7: For manufacturers, the share of air shipping in exports is positively associated with the relevance to timeliness.

To control other factors that may affect the modal selection of international transport, this study includes the value-to-weight ratio, and the ratio of air shipping charge to ocean shipping charge in the regression model.

The research framework is developed as Figure 4-2.

Figure 4-2 Research Framework of Essay Two



4.3 Estimation Models and Data

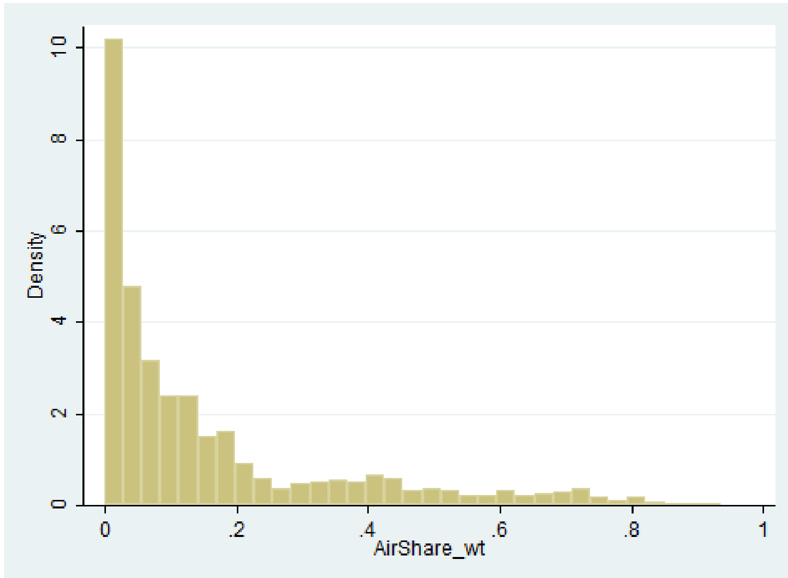
To test the hypotheses above, we develop an inventory model for Hypotheses 1 and 1a and an air share model for Hypotheses 2 to 7. For the inventory model, this study, referring to the models developed by Chen et al. (2005, 2007) and Han et al. (2008), uses inventory days of finished goods (INV) to measure inventory performance. Based on the literature, inventory days of finished goods are associated with exports (Han et al. 2008). Accordingly, this study focuses on the relationship between inventory days of finished goods and the use of air shipping in exports. The main explanatory variables are air share (AIRSHARE), measured by air export value over the sum of air and ocean export values, and the square term of air share (SQ_AIRSHARE). Based on the literature discussed above, this study includes the variables that affect inventory performance as control variables, including positive sales surprise (PSURPRISE), coefficient of variation in demand (CVD), firm size (SIZE), gross margin (GM), weighted average cost of capital (CAPITAL), the ratio of exports to total shipment value (EXRATIO), the ratio of IT investment to shipment value (ITRATIO), the relevance to timeliness (TIMELINESS), and time dummies (YEAR). This study does not use industry fixed-effects because of the concern with multi-collinearity. Most independent variables vary by industry and are considered a more sophisticated form of industry dummies. This study tested an industry fixed-effect model in which the independent variables are industry dummy variables and found it leads to multi-collinearity. After adding industry dummy variables, the scores of VIF (the variance inflation factor) increased and signs flipped to the opposite direction for some variables, showing the existence of multi-collinearity in the model.

For the air share model, the dependent variable, AIRSHARE, is estimated by positive sales surprise (PSURPRISE), the coefficient of variation in demand (CVD), firm size (SIZE), gross margin (GM), weighted average cost of capital (CAPITAL), and the relevance to timeliness (TIMELINESS) while controlling for the value-to-weight ratio (VWRATIO), the ratio of air shipping charge to ocean shipping charge (AORATIO), and time dummies (YEAR).

Obviously, the inventory model and the air share model have common independent variables such as PSURPRISE, CVD, SIZE, GM, CAPITAL, TIMELINESS, and YEAR. These factors impact both the air share and inventory days. It is likely that the error terms of the inventory model and the air share model are correlated. In addition, the inventory days and the air share could be both decided by firms and their characteristics, leading to endogeneity. Hence, we use the two-stage least squares (2SLS) technique to estimate the model. All the identified structural equations are estimated simultaneously in 2SLS. In the first stage, this technique regresses air share on exogenous variables. In the second stage, the estimated air share (P_AIRSHARE) and its square term (P_SQ_AIRSHARE) are used as regressors in the equation of inventory days, to calculate the estimates of the identified equations (Kennedy, 2003).

For estimating the air share model, the OLS (ordinary least square) regression technique is first used to generate the base results. Then, the results of a Tobit model adopting the maximum likelihood (MLE) technique are used to compare with the OLS result. There are two reasons for using a Tobit model in the air share model. First, the dependent variables, the air shares, are strictly between 0 and 1. The OLS may generate a negative or greater-than-one predicted value for the dependent variables. In addition, after examining the data distribution (see Figure 4-3), it shows that data distribution is skewed to the right and censored at 0. Using a Tobit model with the MLE will avoid the asymptotic bias of OLS and generate more efficient estimation of coefficients (Kennedy, 2003). In the second stage, the predicted value of the first stage is inserted into the air share model. The OLS technique is used to estimate the inventory days of finished goods.

Figure 4-3 Histogram of Air Share



The structural equations are developed as follows. Except for AORATIO, this study uses the numbers of export in Air Share Model and attach an "EX" attached to each variable related to exports. Subject to data availability, the ratio of import air-to-ocean shipping charge is used as a proxy for the ratio of export shipping charge. The definition of each variable is explained below.

<u>Air Share Model (The First Stage)</u>

$$EX\ AIRSHARE_{it} = a0 + a1\ PSURPRISE_{it} + a2\ CVD_{jt} + a3\ SIZE_{it} + a4\ GM_{it} + a5\ CAPITAL_{jt} + a6\ TIMELINESS_{it} + a7\ EX\ VWRATIO_{it} + a8\ IM\ AORATIO_{it} + \sum a9_t YEAR_t + \square_{it} \quad (1)$$

, where i represents the 6-digit NAICS industry level, j represents the 3-digit NAICS industry level, and t represents year during 2002-2009.

Inventory Model (The Second Stage)

INV_{it} = b0 + b1 P_EX $AIRSHARE_{it}$ + b2 P_SQ_EX $AIRSHARE_{it}$ + b3 $PSURPRISE_{it}$ + b4 CVD_{jt} + b5 $SIZE_{it}$ + b6 GM_{it} + b7 $CAPITAL_{jt}$ + b8 $TIMELINESS_{it}$ + b9 $EXRATIO_{it}$ + b10 $ITRATIO_{it}$ + $\sum b11_t$*$YEAR_t$ + ε_{it} (2)

, where i represents the 6-digit NAICS industry level, j represents the 3-digit NAICS industry level, and t represents year during 2002-2009.

The panel data are collected at 6-digit NAICS industry level for 270 sub-industries during 2002-2009 for most variables except for CVD and CAPITAL which are only available at the 3-digit NAICS industry level. There are 2,160 observations (270 industries x 8 years) in total. Data is primarily collected from the U.S. exporters of merchandise database and the Annual Survey of Manufacturers (ASM) from the U.S. Census Bureau. The details about definition and data collection are described below.

- INV: The inventory days for finished goods is calculated as follows.

$$\text{INV} = \frac{\text{Finished Goods Inventory Value}}{(\text{Cost of Raw Materials} + \text{Value Added})} \times 365$$

  The data for inventory value, the cost of raw materials, and value added are collected from the ASM conducted by the Census Bureau at the 6-digit NAICS industry level from 2002-2009. The inventory value of finished goods is the value at the end of year for the goods that are the final output and still within ownership of the manufacturer’s establishment. Consistent with the model design of Rajagopalan and Malhotra (2001), the cost of goods sold is measured as the summation of direct material costs and value added.

- AIRSHARE: Air share is collected from the U.S. exporters of merchandise databases at the 6-digit NAICS code industry level from 2002-2009. It is the weight share calculated by the U.S. exports to the world through air transport over the summation of air export weight and ocean export weight for 6 digit NAICS industry i in year t. Exports by ground transportation are excluded from the calculation. It is hypothesized that AIRSHARE is negatively associated with INV.

$$\text{AIRSHARE} = \frac{\text{Export by Air}}{(\text{Export by Air} + \text{Export by Ocean})}$$

- P_AIRSHARE: A predicted value of AIRSHARE by the air share model. Hypothesis 1 implies a negative sign for P_AIRSHARE on INV.
- P_SQAIRSHARE: A square term of P_AIRSHARE. Based on Hypothesis 1a, a positive sign is expected for P_AIRSHARE on INV.
- PSURPRISE: The positive sales surprise is measured by the following equation.

$$\text{PSURPRISE}_{it} = \frac{\text{Sales}_{it}}{\text{Forecast}_{it}} - 1 \quad \text{if Sales}_{it} > \text{Forecast}_{it}$$
$$\text{PSURPRISE}_{it} = 0 \qquad \text{if Sales}_{it} < \text{Forecast}_{it}$$

$\text{Forecast}_{it} = a + b\,(t - 1996)$, while a and b are estimated from the Sales_i of past five years.

The positive sales surprise is calculated as the percentage of actual sales over forecast, which is predicted by the linear trend of annual sales for the past five years when it is positive. The data is collected from the ASM and calculated at the 6-digit NAICS industry level by year. The literature shows that a positive sales surprise implies more demand than expected and thus leads to lower inventory levels. Based on Hypothesis 2, a positive sign is expected for PSURPRISE on AIRSHARE.

- CVD: The coefficient of variation in demand is calculated by the standard deviation over the mean monthly shipment value within one year for the 3-digit NAICS industry j in year t. The data is collected from the Manufacturers' Shipments, Inventories, and Orders (M3) survey conducted by the U.S. Census Bureau. It is expected that higher demand variation leads to higher inventory levels because of higher safety stock. Hypothesis 3 implies a positive sign for CVD on AIRSHARE.

- SIZE: This variable represents the average firm size of the top 4 firms for 6-digit NAICS industry i in year t. The average firm size is calculated by the shipment value in an industry times the market share of top four firms in an industry and divided by four and transformed by logarithm. The data for the shipment value is collected at the 6-digit NAICS industry level from the ASM conducted by the U.S. Census Bureau and the concentration ratio (CR4) is collected from the 2002 and 2007 Economic Census. The same concentration ratio is applied for two years pre and post census survey. For example, the concentration ratios are the same during 2002 and 2004 and during 2005 and 2009, respectively. This variable captures the firm size of major players rather than the average firm size in an industry to avoid the dilution from many small players in one industry. Hypothesis 4 predicts a negative sign for SIZE on AIRSHARE.
- GM: Gross margin is a ratio calculated by the difference between shipment value and the summation of direct material costs and direct labor costs over shipment value for 6-digit NAICS industry i in year t. The data is calculated from the 2002-2009 ASM. It is expected that GM is positively associated with INV and Hypothesis 5 suggests a positive sign for GM on AIRSHARE.
- CAPITAL: The cost of capital is measured by the median of the weighted average cost of capital in the U.S. using CAPM method for the 3-digit NAICS industry j in year t. The data is collected from Morningstar.com. It is expected that CAPITAL is negatively

associated with INV. Based on Hypothesis 6, a positive sign is expected for CAPITAL on AIRSHARE.

- TIMELIENESS: This variable captures the percentage of the shipment value comprised of the parts and components for 6-digit NAICS industry i in year t. Consulted with Hummels and Schaur (2012), this study identifies the commodity description that includes the key word "part" or "component" which means that they are intermediate inputs of production and relevant to the timeliness in the manufacturing process. For example, the exported items below (see Table 4-1) are considered commodities related to timeliness. These items are identified and converted to the 6-digit NAICS code. The TIMELINESS is measured by the share of these items over the total export weight for the 6-digit NAICS industry i in year t. The data is collected from the U.S. exporters of merchandise database.

Table 4-1 Examples of Commodities Related to Timeliness

NAICS Code	HS Code	Description
327390	6810910000	PREFABRICATED STRUCTURAL COMPONENTS FOR BUILDING OR CIVIL ENGINEERINGMADE OF CONCRETE, CEMENT OR ARTIFICIAL STONE
333999	8421990080	PARTS OF MACHINERY AND APPARATUS FOR FILTERING OR PURIFYING LIQUIDS AND GASES, NESOI

It is expected that the industry with more items relevant to timeliness uses more air shipping and thus a positive sign for TIMELINESS on AIRSHARE.

- VWRATIO: The real value-to-weight ratio is measured by the ratio of U.S. export value to U.S. export weight for 6-digit NAICS industry i in year t and adjusted by the PPI of total manufacturing industry. The data is calculated from U.S. exporters of merchandise database published by the U.S. Census Bureau. The export value represents the selling price, including inland freight, insurance, and other charges to the port of exportation and excluding international freight and duties. Firms tend to ship high value-to-weight items through air because of the relatively lower ratio of transportation charges to product value, and thus it is expected that VWRATIO is positively associated with AIRSHARE.

- AORATIO: The ratio is calculated by the air shipping charge per kilogram to ocean shipping charge at the 6-digit NAICS industry level. Because shipping charge data is only available for import shipments on the U.S. Importers of Merchandise database, import shipping charge is used as a proxy to the export shipping charge. The shipping charge includes the aggregate cost of all freight, insurance, and other charges excluding U.S. import duties from the carrier at the port of exportation to the carrier at the first port of entry in the U.S. It is found that there are some outliers of extremely low or high value for this variable. To reduce the potential biases from these outliers, this study adopts Winsorization technique which replaces the high extreme values with 99.5 percentiles and low extreme values with 0.5 percentiles (see examples in Chen, et al., 2005, 2007; Han, et al., 2012). Based on the demand rule, it is expected that AORATIO is negatively associated with AIRSHARE.
- YEAR: Year is a dummy variable for year t with the base year of year 2002. The model includes 7 year-dummy variables for year 2003-2009.
- EXRATIO: The export ratio is calculated by the U.S. export value over total shipment value for 6-digit NAICS industry i in year t. While the U.S. export value is collected from U.S. Exports of Merchandise database, the shipment value is retrieved from the ASM at a 6-digit NAICS industry level. Based on the finding of Han et al. (2008),

higher export ratios lead to more finished-goods inventory held by the manufacturers. It is expected that EXRATIO is positively associated with INV.

- ITRATIO: The IT RATIO is calculated by the ratio of annual capital expenditure on computer and data processing equipment over total shipment value for 6-digit NAICS industry i in year t. The data is collected from the ASM during 2002-2009. The investment in IT could lower ordering costs so as to achieve a lower inventory level. Hence, ITRATIO is expected to be negatively associated with INV.

4.4 Results

Table 4-2 reports the descriptive statistics of the variables used in the models and their trends during 2002-2009. The inventory days of finished goods show a worsening trend from 17.13 days in 2005 to 19.42 days in 2009, especially during the economic downturn of 2008-2009, accompanied by shrinking positive sales surprises during 2008 and 2009. The share of export over shipment value increases from 21.2% in 2002 to 26% in 2009. The use of air shipping in trade is on a slightly upward trend from 15.8% in 2002 to 16.3% in 2009. In the meanwhile, the unit cost of air shipping fluctuates within a narrow range between 11.21 times and 9.97 times. The cost of capital is on a slightly upward trend from 11.2% in 2002 to 11.7% in 2009.

Table 4-2 Descriptive Statistics

	Total					2002	2003	2004	2005	2006	2007	2008	2009
Variable	Obs	Mean	Std. Dev.	Min	Max	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
INV	2160	17.93	12.02	0.145	129.839	18.36	18.07	17.29	17.13	17.34	17.53	18.30	19.42
AIRSHARE	2160	0.163	0.201	0.000	0.936	0.158	0.159	0.167	0.161	0.170	0.167	0.162	0.163
PSURPRISE	2160	0.096	0.542	0.000	22.821	0.042	0.132	0.108	0.207	0.114	0.105	0.046	0.013
CVD	2160	0.076	0.028	0.020	0.282	0.075	0.075	0.082	0.076	0.076	0.077	0.084	0.061
SIZE	2160	1,756,938	4,015,947	17,110	87,000,000	1,444,948	1,475,762	1,574,892	1,780,215	1,895,564	2,032,984	2,123,746	1,727,392
GM	2160	0.411	0.117	0.091	0.867	0.416	0.417	0.418	0.410	0.408	0.410	0.398	0.411
CAPITAL	2160	0.112	0.022	0.057	0.168	0.112	0.100	0.104	0.109	0.108	0.120	0.125	0.117
TIMELINESS	2160	0.107	0.187	0.000	1.000	0.094	0.103	0.105	0.100	0.101	0.103	0.098	0.148
VWRATIO	2160	31.59	83.51	0.05	1185.14	32.31	31.81	32.80	34.04	38.90	42.73	42.11	35.35
AORATIO	2160	10.56	8.06	0.83	74.32	11.21	10.78	10.07	10.28	9.97	10.26	10.77	11.10
EXRATIO	2160	0.249	0.289	0.000	2.543	0.212	0.219	0.243	0.246	0.262	0.266	0.285	0.260
ITRATIO	2160	0.0018	0.0019	0.000	0.043	0.0022	0.0021	0.0017	0.0017	0.0018	0.0015	0.0018	0.0016

*Average across all industries

Table 4-3 shows the characteristics of each manufacturing industry at the 3-digit NAICS industry level. The statistics for each industry group are a simple average of the data points at the 6-digit NAICS sub-industry level. While apparel, beverage and tobacco manufacturing industries have longer inventory days, printing and transportation equipment manufacturing industries have the leanest inventories. Computer and electronic product manufacturing has the highest air share at 51.4%, followed by miscellaneous' 30.6%, apparel's 28.9%, and printing's 26.9%. The industries with high air shares usually have high value-to-weight ratios. In addition, the apparel industry has the highest positive sales surprise at 20.5%, followed by machinery manufacturing and computer and electronic product manufacturing. In the correlation table (see Table 4-4), air share has a significantly positive association with value-to-weight ratio, demand variation, gross margin, cost of capital and negative correlation with air-to-ocean charge ratio. The relationships are consistent with the research hypotheses.

Table 4-3 Industry Summary

3-digit NAICS	Name of Industry	Obs	INV	AIRSHARE	PSURPRISE	CVD	GM	SIZE	CAPITAL	TIMELINESS	VWRATIO	AORATIO	EXRATIO	ITRATIO
311	Food mfg	192	14.40	0.020	0.062	0.047	0.401	2,412,889	0.080	0.006	1.658	11.631	0.073	0.0009
312	Beverage & tobacco product mfg	40	32.72	0.008	0.041	0.066	0.596	4,290,020	0.067	0.023	2.336	9.270	0.060	0.0013
313	Textile mills	56	18.35	0.069	0.050	0.070	0.323	511,444	0.103	0.000	5.542	11.505	0.325	0.0016
314	Textile product mills	48	21.68	0.124	0.043	0.071	0.341	558,317	0.103	0.000	6.205	11.034	0.101	0.0014
315	Apparel mfg	32	35.88	0.289	0.205	0.081	0.391	624,729	0.104	0.158	15.150	6.949	0.284	0.0016
316	Leather & allied product mfg	24	28.99	0.183	0.146	0.094	0.361	242,292	0.111	0.112	10.414	6.288	0.576	0.0015
321	Wood product mfg	72	14.47	0.020	0.052	0.095	0.302	694,290	0.116	0.077	1.787	9.680	0.044	0.0014
322	Paper mfg	72	15.49	0.049	0.041	0.034	0.382	2,238,601	0.104	0.003	1.900	12.699	0.181	0.0011
323	Printing & related support activities	16	6.30	0.269	0.042	0.051	0.489	3,283,410	0.105	0.063	13.716	11.364	0.036	0.0047
324	Petroleum & coal products mfg	24	13.03	0.007	0.090	0.146	0.276	17,200,000	0.097	0.000	0.497	21.839	0.027	0.0006
325	Chemical mfg	184	19.02	0.082	0.082	0.053	0.451	3,060,939	0.110	0.002	19.357	14.064	0.251	0.0012
326	Plastics & rubber products mfg	64	19.49	0.063	0.038	0.063	0.364	1,831,605	0.104	0.004	5.154	9.776	0.149	0.0015
327	Nonmetallic mineral product mfg	160	25.94	0.042	0.055	0.092	0.469	495,592	0.114	0.003	2.500	15.913	0.096	0.0013
331	Primary metal mfg	80	13.43	0.103	0.121	0.076	0.255	2,212,566	0.140	0.001	5.802	19.061	0.155	0.0010
332	Fabricated metal product mfg	136	18.70	0.156	0.065	0.063	0.434	819,774	0.100	0.165	23.705	8.856	0.204	0.0018
333	Machinery mfg	264	19.85	0.205	0.201	0.075	0.420	916,347	0.134	0.254	28.799	8.026	0.408	0.0025
334	Computer & electronic product mfg	224	13.41	0.514	0.174	0.106	0.483	1,634,437	0.113	0.136	118.189	8.296	0.544	0.0033
335	Electrical equipment, appliance, & component mfg	112	16.12	0.173	0.088	0.072	0.404	750,360	0.149	0.146	20.920	10.037	0.284	0.0016
336	Transportation equipment mfg	184	9.31	0.185	0.088	0.114	0.327	2,954,515	0.110	0.271	66.056	7.676	0.227	0.0013
337	Furniture & related product mfg	64	11.99	0.051	0.034	0.043	0.408	699,363	0.111	0.120	5.482	6.463	0.066	0.0018
339	Miscellaneous mfg	112	27.88	0.306	0.034	0.070	0.503	660,769	0.110	0.167	81.074	8.198	0.356	0.0031
Total		2160	17.93	0.163	0.096	0.076	0.411	1,756,938	0.112	0.107	31.591	10.557	0.249	0.0018

*Average across all years

** The numbers in this summary table are simple average across observations of each industry group and across year.

Table 4-4 Correlation Table

	1	2	3	4	5	6	7	8	9	10	11	12
1. INV	1											
2. AIRSHARE	-0.0126	1										
3. PSURPRISE	-0.0281	0.0374	1									
4. CVD	-0.0714*	0.2891*	0.0464*	1								
5. SIZE	-0.1697*	-0.0091	-0.0063	0.1302*	1							
6. GM	0.1288*	0.3365*	0.0034	-0.0812*	-0.0933*	1						
7. CAPITAL	-0.0070	0.1661*	0.0392	0.2216*	-0.0957*	-0.1042*	1					
8. TIMELINESS	0.0000	0.2690*	0.0565*	0.1709*	-0.0719*	0.0662*	0.1998*	1				
9. VWRATIO	0.0049	0.6071*	0.0228	0.2127*	0.1416*	0.2410*	0.0564*	0.2004*	1			
10. AORATIO	-0.0509*	-0.2302*	-0.0141	-0.0458*	0.1221*	-0.0940*	-0.0135	-0.1888*	-0.0965*	1		
11. EXRATIO	0.1576*	0.3771*	0.0769*	0.1449*	-0.0795*	0.0863*	0.2064*	0.3257*	0.3953*	-0.0696*	1	
12. ITRATIO	0.0395	0.3777*	-0.0014	0.0787*	-0.0816*	0.2689*	0.0826*	0.1794*	0.2080*	-0.1379*	0.2072*	1

* represents $p<0.05$

Table 4-5 presents the regression results for the air share model which is the first stage equation. While the first column presents the result using OLS technique, the second column uses the Tobit model. The results of OLS and Tobit look very similar. Considering that the Tobit model takes the censored data into account, this study uses the results of the second column in Table 4-5 to examine the Hypotheses 2-7. The interpretation of the coefficients in the Tobit model is different from that in OLS. The distribution of dependent variable in OLS is not constrained, while that in a Tobit model is constrained to be non-negative. Hence, the Tobit estimates must be multiplied by the adjustment factor to make them comparable with OLS estimates (Wooldridge, 2003). In addition, the beta coefficient which is generated by the standardized regression model is usually used to compare the effects of different independent variables on the dependent variable in a multiple regression analysis when the variables are measured in different units. This study uses the beta coefficients to compare the effects of each independent variable on air shares.

In the air share model, the positive sales surprise is not found to have impact on the air share, and thus the Hypothesis 2 is not supported. The coefficient of variation in demand is positively associated with air share at a 0.01 significance level, lending support to Hypothesis 3. It implies that more air shipping is used to manage the large fluctuations in demand. Next to value-to-weight ratio and gross margin, demand variation has the third strongest impact on air share. In addition, firm size is found to be significantly related to air shipping at a 0.01 significance level, and Hypothesis 4 is supported. Because large firms can better leverage the economies of scale and risk pooling to decrease the impact of demand variation, they can afford using slower and less costly transportation options to meet customer's needs. Higher gross margins are positively associated with the use of air shipping in trade, supporting Hypothesis 5. A 10 percentage point increase in gross margin leads to an increase in air share by 3.3 percentage points. The beta coefficient shows that gross margin has the second strongest effect, next to value-to-weight ratio, on air share. High gross margins offer firms more incentive to realize the demand on time and minimize the sales loss. Higher cost of capital is found to be positively related to the air share at a 0.01 significance level, lending support to Hypothesis 6. If cost of capital increases by 1 percentage point, firms will increase their shares of air shipping by 0.86 percentage point. It shows that when a manufacturer has a high cost of capital, it is more likely to use air shipping to decrease inventory days and reduce its need for working capital. Lastly, the results show that the industries with more shipments related to timeliness such as components and parts use more air shipping at a 0.01 significance level, lending support to Hypothesis 7.

For the control variables in the air share model, the signs are all as expected. The results show that the industries with high value-to-weight ratios use more air shipping at a 0.01 significance level. For high-value items, the air shipping charge accounts for a smaller portion of product value, and hence air shipping is more affordable. Furthermore, the ratio of air-to-ocean charge shows a negative sign at a 0.01 significance level as expected. When air shipping charges decrease relative to ocean shipping charges, firms use more air shipping.

Table 4-5   Summary of Estimation Result – The First Stage

DV: AIRSHARE 1st Stage	(1) OLS		(2) Tobit		
	Coefficient	beta	Coefficient	Marginal Effect	beta
PSURPRISE	0.0020	0.01	0.0020	0.0018	0.01
	(0.34)		(0.35)		
CVD	1.1571***	0.16	1.1540***	1.0072	0.16
	(9.66)		(9.66)		
SIZE	-0.0106***	-0.06	-0.0105***	-0.0092	-0.06
	(-3.90)		(-3.90)		
GM	0.3757***	0.22	0.3760***	0.3282	0.22
	(13.43)		(13.49)		
CAPITAL	0.9849***	0.11	0.9873***	0.8618	0.11
	(5.98)		(6.02)		
TIMELINESS	0.0789***	0.07	0.0787***	0.0687	0.07
	(4.45)		(4.46)		
VW_RATIO	0.0012***	0.50	0.0012***	0.0010	0.50
	(29.31)		(29.41)		
AO_RATIO	-0.0034***	-0.13	-0.0034***	-0.0030	-0.14
	(-8.53)		(-8.66)		
Constant	-0.0614		-0.0614		
	(-1.26)		(-1.27)		
INDUSTRY	Not Included		Not Included		
YEAR	Included		Included		
Observations	2,160		2,160		
R-squared or Pseudo R-squared for Tobit	0.494		-1.852		

Dependent varilable is export air weight share; t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

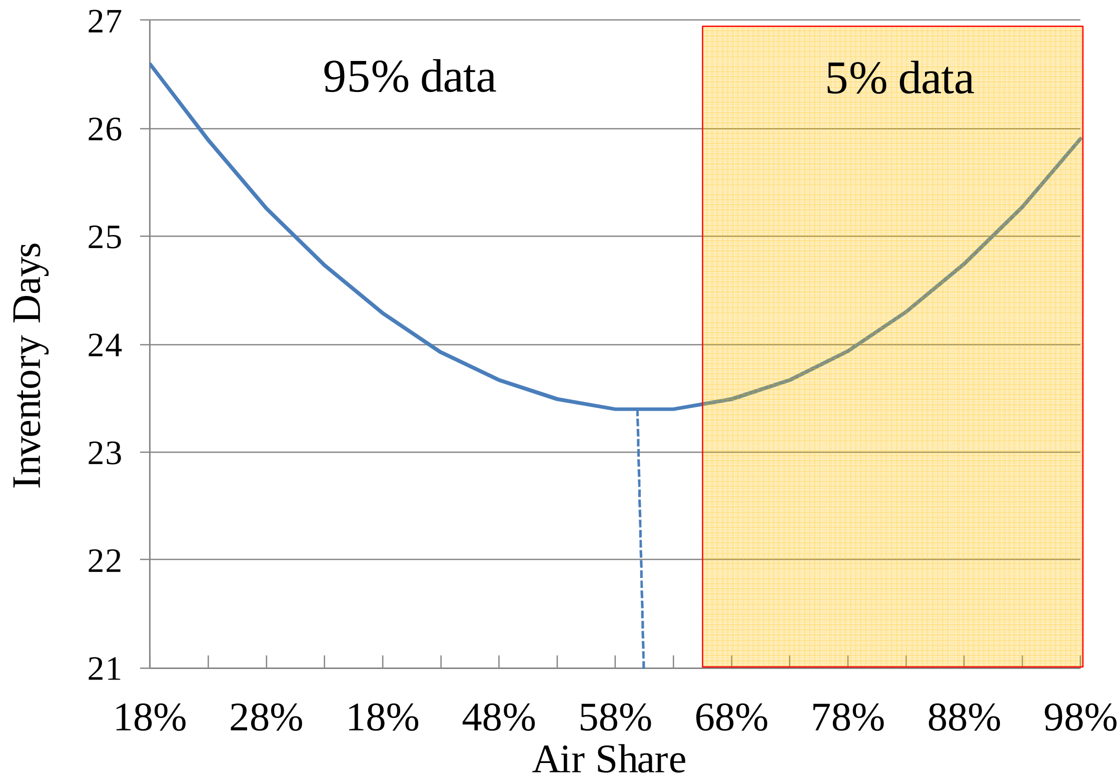
Table 4-6 presents the second-stage estimation results for the inventory model. The first column shows the results using the OLS prediction of air share from the first stage, while the second column adds the square term of the predicted OLS air share. The third column reports the estimation results using the Tobit projected air share, while the fourth column adds the square term of projected air share. Like the results of the first stage, the results of OLS and the Tobit models look very similar, while the coefficients using Tobit are generally smaller than those using OLS. The tests of Hypotheses 1a and 1b are mainly based on the third and fourth columns because the Tobit models in the first stage consider the censored data distribution. In the inventory model without the square term, the air share is not found to have any impact on the inventory days. After adding the square term, both the air share and its square term become significant, showing the relationship between air share and inventory days is strictly nonlinear, and the reduction in inventory days is at a diminishing rate. Hence, Hypothesis 1a is supported at a 0.05 significance level when there is a square term, and Hypothesis 1b is supported at a 0.1 significance level. Based on the coefficients of air share and its square term, it shows that the turning point is located at 60% (=0.8063/(2*0.6698)) air share. That is, beyond 60% air share, the reduction inventory days from increased air share will decrease. For example, Figure 4-4 shows the relationship between air share and inventory days for the apparel manufacturing industry. When the apparel manufacturing industry increases its air share by 10 percent points from 17.7 percent to 27.7 percent, the inventory days is reduced by 1.33 days to 25.26 days, and the inventory days reach the minimum at 23.39 days when air share is 60 percent. Beyond 60 percent air share, an additional increase in air share does not lead to further reduction in inventory days. The distribution of data shows that 95 percent of air share falls between 0 percent and 60 percent, implying that the negative relationship between air share and inventory days is more common. In addition, the beta coefficients show that the air share and its square term are the third and fifth important factors, respectively, determining the air share.

Table 4-6 Summary of Estimation Result – The Second Stage

DV: ln(INV) 2nd Stage	(1) OLS Coefficient	beta	(2) OLS Coefficient	beta	(3) OLS Coefficient	beta	(4) OLS Coefficient	beta
P_AIRSHARE (1st stage OLS)	-0.1215	-0.02	-0.8231**	-0.16				
	(-0.77)		(-2.25)					
P_SQ_AIRSHARE (1st stage OLS)			0.6833**	0.11				
			(2.13)					
P_AIRSHARE (1st stage Tobit)					-0.1212	-0.02	-0.8063**	-0.16
					(-0.76)		(-2.22)	
P_SQ_AIRSHARE (1st stage Tobit)							0.6698**	0.11
							(2.10)	
GM	0.2058	0.03	0.4357**	0.07	0.2057	0.03	0.4299**	0.07
	(1.32)		(2.30)		(1.32)		(2.28)	
PSURPRISE	-0.0396	-0.03	-0.0384	-0.03	-0.0396	-0.03	-0.0385	-0.03
	(-1.51)		(-1.47)		(-1.51)		(-1.47)	
CAPITAL	0.5802	0.02	1.1206	0.03	0.5800	0.02	1.1078	0.03
	(0.76)		(1.39)		(0.75)		(1.37)	
CVD	-4.2729***	-0.17	-3.6018***	-0.14	-4.2739***	-0.17	-3.6218***	-0.14
	(-7.03)		(-5.26)		(-7.04)		(-5.31)	
SIZE	-0.1898***	-0.32	-0.1975***	-0.33	-0.1898***	-0.32	-0.1974***	-0.33
	(-15.43)		(-15.41)		(-15.43)		(-15.41)	
EXRATIO	0.4274***	0.17	0.4341***	0.18	0.4273***	0.17	0.4336***	0.18
	(7.45)		(7.56)		(7.45)		(7.55)	
ITRATIO	-5.0024	-0.01	-2.8737	-0.01	-5.0016	-0.01	-2.9163	-0.01
	(-0.61)		(-0.35)		(-0.61)		(-0.35)	
TIMELINESS	-0.1504*	-0.04	-0.0933	-0.02	-0.1504*	-0.04	-0.0945	-0.02
	(-1.78)		(-1.05)		(-1.78)		(-1.07)	
Constant	5.3727***		5.3397***		5.3728***		5.3416***	
	(23.42)		(23.24)		(23.42)		(23.26)	
INDUSTRY	Not Included		Not Included		Not Included		Not Included	
YEAR	Included		Included		Included		Included	
Observations	2,160		2,160		2,160		2,160	
R-squared	0.169		0.171		0.169		0.171	

Dependent varilable is ln(INV); t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 4-4 Relationship between Air Share and Inventory Days
Apparel Manufacturing Industry (Base Air Share = 17.7%)



For the control variables in the inventory model, a higher positive sales surprise is negatively associated with inventory days although the coefficient is not statistically significant. The coefficient of variation in demand is found to be negatively associated with inventory levels. This finding is counterintuitive because it is expected that higher variation in demand will lead to more safety stock and thus higher inventory levels given the committed service level, as suggested by Rumyantsev and Netesine (2007). However, Chopra et al. (2004) indicates the relationship between safety stock and demand uncertainty, lead time, and lead uncertainty is based on the assumption of normal distribution. Once the normality assumption is violated, the relationship may not hold. It requires more research on the distribution pattern of demand. The firm size of the top four firms is found to have negative relationship with inventory levels because of economies of scale, risk pooling, and bargaining power of large firms and has the strongest impact on air share. This finding is consistent with Rumyantsev and Netesine (2007) and Han et al. (2008). A higher gross margin is found to be positively associated with inventory levels, a result similar to the finding of Gaur et al. (2005), which argue that higher service levels are set for high-margin products in the retail industry. The results of this study show that the positive relationship between gross margin and inventory level also hold for the manufacturing industry. Higher costs of capital are not found to have statistically significant impact on inventory levels. The percentage of intermediate products over sales volume is not found to have an impact on inventory days. In addition, a higher degree of globalization measured by export ratio leads to longer inventory days, as found by Han et al. (2008). The result of this study again supports the argument that manufacturers have to keep a higher inventory levels in response to globalization. Furthermore, there is no solid evidence showing that an investment in computer and data processing equipment can effectively lower inventory days for finished goods.

4.5 Discussion

In Essay One, the results for the effect of the industry characteristics on air share for exports are presented using the data at the country level and the 3-digit NAICS industry level. In Essay Two, the same variables are included in the export air share model using the 6-digit NAICS industry level data. The results of these two essays are compared and contrasted in Table 4-7. Except for the positive surprise and demand variation, the results of two essays are very consistent. Most variables show the same sign at a 0.01 significance level. In Essay One, the positive sales surprise is found to be positively associated with air share at a 0.01 significance level using the 3-digit NAICS industry data, but this relationship is not found at the 6-digit NAICS industry level. In addition, demand variation is found to have a significantly positive impact on air share in Essay Two but not significant in Essay One.

Table 4-7 Comparison of Results in Essay One and Essay Two

DV: AIRSHARE	Essay One Tobit			Essay Two Tobit		
	Coefficient	Marginal Effect	beta	Coefficient	Marginal Effect	beta
PSURPRISE	0.0885*	0.0755	0.05	0.0020	0.0018	0.01
	(1.79)			(0.35)		
CVD	-0.1338	-0.1141	-0.02	1.1540***	1.0072	0.16
	(-1.12)			(9.66)		
SIZE	-0.0452***	-0.0386	-0.23	-0.0105***	-0.0092	-0.06
	(-12.00)			(-3.90)		
GM	0.2657***	0.2266	0.14	0.3760***	0.3282	0.22
	(6.57)			(13.49)		
CAPITAL	0.6616***	0.5643	0.08	0.9873***	0.8618	0.11
	(3.94)			(6.02)		
TIMELINESS	0.0946***	0.0807	0.08	0.0787***	0.0687	0.07
	(4.23)			(4.46)		
VW_RATIO	0.0016***	0.0014	0.50	0.0012***	0.0010	0.50
	(23.34)			(29.41)		
AO_RATIO	-0.6473***	-0.5521	-0.09	-0.0034***	-0.0030	-0.14
	(-4.59)			(-8.66)		
Constant	0.2968***			-0.0614		
	(4.97)			(-1.27)		
INDUSTRY	Not Included			Not Included		
YEAR	Included			Included		
Observations	1,954			2,160		
R-squared or Pseudo R-squared for Tobit	-0.7217			-1.852		

Dependent varilable is export air weight share; t-statistics in parentheses

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

Table 4-8 Projection of Results

	Apparel Manufacturing		
	Air Share Original	Air Share New	Diff.
Air Share (%)	17.7%	27.7%	10%
Export by Air (kg)	38,335,691	59,943,915	21,608,224
Diff. in air and ocean charges ($)	2.16		
Changes in shipping costs (A)			46,744,356
Inventory Days	26.60	25.26	-1.3
Inventory Value ($)	1,905,157,012	1,809,579,913	-95,577,099
Cost of Capital (%)	10.4%		
Cost of Capital ($) (B)	198,160,144	188,218,931	-9,941,213
Net change in cost (A)+(B)			36,803,143
Breakeven Point of Carrying Cost*	**48.9%**		
Carrying Cost ($) (C)	931,764,385	885,020,030	-46,744,356
Net change in cost (A)+(C)			0

The findings of this study have important empirical implications to practioners. This study quantifies the relationship between air shipping and inventory days of finished goods, and this finding can be widely applied to many manufacturing industries. Based on the results, the relationship between air share and inventory is nonlinear. While more use of air shipping shortens inventory days, the decrease is at a diminishing rate. This study uses the estimation results of the inventory model to project the impact of the changes in air shares on the inventory levels and inventory carrying costs (see Table 4-8). For example, when the apparel manufacturing industry increases its air share by 10 percent points from 17.7% to 27.7%, the weight carried by air export increases from 38.3 million kilograms to 59.9 million kilograms. Knowing that the difference in shipping rate between air and ocean is $2.16/kg, this switch from ocean to air increases transportation cost by $46.7 million (21.608 million kilograms * $2.16/kg). Meanwhile, it is projected that the increase in air share by 10 percent points from 17.7% to 27.7% will decrease the inventory days from 26.6 days to 25.26 days, implying that the holdings for finished goods inventory are reduced from $1.905 billion to $1.810 billion. This increase in the share of air shipping contributes to lowering inventories by $95.6 million. The decreased inventory holdings imply a lower requirement for working capital. Knowing that the cost of capital for apparel manufacturing industry is 10.4%, the savings in the cost of capital from the decreased inventory holdings is $9.9 million (=$95.6 m * 10.4%). The net cost increase considering incremental transportation costs and the saving in cost of capital is $36.8 million (=$46.7m-$9.9m).

Based on the net cost increase above, it seems that the increased transportation costs cannot be justified. However, cost of capital does not represent the whole picture of inventory carrying cost. Based on Richardson (1995), inventory carrying costs include not only cost of capital but also the costs of taxes, insurance, warehousing, physical handling, inventory control, obsolescence, and deterioration, and total carrying cost ranges between 25-55% (see Table 4-9). Cost of capital accounts for only about a quarter of total inventory carrying costs, while the cost of obsolesce accounts for another quarter. Further calculations in Table 4-8 show that if the total inventory carrying costs are 48.9 percent (=change in shipping cost/saving in inventory value), the increased transportation costs can be completely offset by the savings from decreased inventory carrying cost. From the perspective of total cost minimization, the 48.9 percent is considered a break-even point (BEP) of inventory carrying cost for the decision of transportation modal selection in global supply chains. If the total inventory carrying costs exceed the BEP, it implies the increase in transportation costs can be completely offset by the decrease in carrying cost. This industry could consider using more air shipping in their global supply chains. The BEP for each industry is calculated and summarized in Table 4-10.

Table 4-9 Ranges of Inventory Carrying Costs

Item	% of Product Value
Cost of Money	6% - 12%
Taxes	2% - 6%
Insurance	1% - 3%
Warehouse Expenses	2% - 5%
Physical Handling	2% - 5%
Clerical & Inventory Control	3% - 6%
Obsolescence	6% - 12%
Deterioration & Pilferage	3% - 6%
Total	25% - 55%

*Source: Richardson, H., 1995. Control your costs then cut them. Transportation & Distribution.

Drawing a line at 55% BEP, it is found that there are still great opportunities for some industries such as furniture manufacturing, fabricated metal product manufacturing, miscellaneous manufacturing, textile product mills, and apparel manufacturing to use more air shipping. The computer and electronic product manufacturing shows an extremely high BEP which is not consistent with its high air share. The primary reason is that the air share for this industry is already high at about 50%, and thus the inventory reduction from the increase in air share is not as obvious as that of other industries. A counterintuitive finding is that the BEP for furniture and related products manufacturing is only 13.2%, and the level of BEP is contributed by the lowest air-to-ocean shipping charge ratio (AORATIO) at five times. More studies are needed to uncover the reason for the low AORATIO and BEP for the furniture manufacturing industry.

Nevertheless, the analysis above is only based on total cost minimization. To maximize a firm's profit, it is crucial to take revenue into consideration. In Essay One, it shows that firms use more air shipping when there is a positive sales surprise. his means that firms could utilize air shipping to realize demand surges on time and reduce sales losses. Given the nonlinear relationship between air share and inventory days, this study uses optimization tool provided by the Solver of MS Excel 2007to find the optimal air share that maximize total profit for each industry considering different scenarios of sales gain from increased air shares. First, four scenarios are developed and total carrying cost is assumed to be 50% for all scenarios. Scenario 1 is the base case assuming that there is no sales gain due to more usage of air shipping. Scenarios 2, 3, and 4 assume that the sales gain per 10-percent-point increase in air share is 1%, 5%, and 10% of export sales, respectively. The profit ratio is assumed to be 5% of sales for all scenarios. The objective function of optimization is to maximize the total profit which is equal to savings in carrying costs minus incremental transportation costs plus gain from the profit of reduced sales losses. The industry summary for optimal air share is shown in Table 4-11. The numbers for optimal air shares have included suggested changes.

Table 4-10 Industry Summary of Breakeven Points of Inventory Carrying Cost

Industry	Industry	Value-to-Weight Ratio	AORATIO	Inventory Days	Air Share	BEP for Carrying Cost	Example Firm
337	Furniture & related product mfg	5.56	4.99	12.9	5.0%	14.3%	STEELCASE
332	Fabricated metal product mfg	10.11	8.66	16.4	15.3%	25.6%	ILLINOIS TOOL WORKS
339	Miscellaneous mfg	54.84	8.44	25.7	23.0%	33.0%	3M
314	Textile product mills	5.46	9.40	17.4	9.8%	43.8%	INTERFACE
315	Apparel mfg	10.59	6.70	26.6	17.7%	48.9%	GUESS
326	Plastics & rubber products mfg	4.89	10.65	17.2	5.3%	57.3%	GOODYEAR TIRE & RUBBER
323	Printing & related support activities	10.94	8.81	6.5	32.4%	69.6%	MCGRAW-HILL
335	Electrical equipment, appliance, & component	15.95	8.71	15.6	13.5%	77.3%	GENERAL ELECTRIC
327	Nonmetallic mineral product mfg	1.81	26.98	18.2	3.3%	79.1%	OWENS CORNING
336	Transportation equipment mfg	19.36	9.45	6.6	5.8%	81.2%	GENERAL MOTORS
333	Machinery mfg	16.20	9.37	19.4	10.7%	90.2%	CATERPILLAR
312	Beverage & tobacco product mfg	1.16	13.60	16.1	0.5%	88.5%	PEPSI
331	Primary metal mfg	3.40	36.40	15.3	3.0%	141.7%	ALCOA
316	Leather & allied product mfg	7.18	6.63	30.9	9.6%	171.0%	NIKE
313	Textile mills	4.64	12.43	16.9	3.8%	181.4%	ALBANY INTERNATIONAL
321	Wood product mfg	0.42	12.86	16.0	0.3%	202.6%	UNIVERSAL FOREST PRODUCTS
334	Computer & electronic product mfg	124.60	8.52	9.6	49.9%	372.2%	APPLE
311	Food mfg	0.68	15.73	13.2	0.4%	270.3%	HERSHEY
324	Petroleum & coal products mfg	0.25	25.38	10.1	0.0%	425.5%	SHELL
325	Chemical mfg	1.99	43.11	17.5	1.0%	498.2%	JOHNSON & JOHNSON
322	Paper mfg	0.68	21.35	13.9	0.6%	527.2%	KIMBERLY CLARK

Table 4-11 Industry Summary of Optimal Air Shares

Industry	Value-to-Weight Ratio	AORATIO	Inventory Days	Air Share	Scenario 1: Optimal Air Share with 50% Carrying Cost without Sales Gain	Scenario 2: Optimal Air Share with 50% Carrying Cost & 1% Sales Gain*	Scenario 3: Optimal Air Share with 50% Carrying Cost & 5% Sales Gain**	Scenario 4: Optimal Air Share with 50% Carrying Cost & 10% Sales Gain***
Furniture & related product mfg	5.56	4.99	12.9	5.0%	45.81%	46.84%	50.94%	56.07%
Fabricated metal product mfg	10.11	8.66	16.4	15.3%	39.81%	41.57%	48.61%	57.42%
Miscellaneous mfg	54.84	8.44	25.7	23.0%	38.90%	42.54%	57.13%	75.36%
Printing & related support activities	10.94	8.81	6.5	32.4%	28.49%	31.41%	43.10%	57.71%
Apparel mfg	10.59	6.70	26.6	17.7%	23.56%	25.45%	33.02%	42.48%
Computer & electronic product mfg	124.60	8.52	9.6	49.9%	20.92%	35.88%	95.75%	100.00%
Textile product mills	5.46	9.40	17.4	9.8%	20.44%	21.91%	27.80%	35.17%
Plastics & rubber products mfg	4.89	10.65	17.2	5.3%	3.06%	4.99%	12.70%	22.35%
Wood product mfg	0.42	12.86	16.0	0.3%	0.00%	0.00%	0.00%	0.00%
Food mfg	0.68	15.73	13.2	0.4%	0.00%	0.00%	0.00%	0.00%
Transportation equipment mfg	19.36	9.45	6.6	5.8%	0.00%	0.00%	38.86%	97.77%
Electrical equipment, appliance, & component	15.95	8.71	15.6	13.5%	0.00%	1.22%	23.13%	50.51%
Machinery mfg	16.20	9.37	19.4	10.7%	0.00%	0.00%	8.64%	37.39%
Nonmetallic mineral product mfg	1.81	26.98	18.2	3.3%	0.00%	0.00%	0.00%	0.00%
Primary metal mfg	3.40	36.40	15.3	3.0%	0.00%	0.00%	0.00%	0.00%
Leather & allied product mfg	7.18	6.63	30.9	9.6%	0.00%	0.00%	0.00%	0.00%
Paper mfg	0.68	21.35	13.9	0.6%	0.00%	0.00%	0.00%	0.00%
Beverage & tobacco product mfg	1.16	13.60	16.1	0.5%	0.00%	0.00%	0.00%	0.00%
Petroleum & coal products mfg	0.25	25.38	10.1	0.0%	0.00%	0.00%	0.00%	0.00%
Chemical mfg	1.99	43.11	17.5	1.0%	0.00%	0.00%	0.00%	0.00%
Textile mills	4.64	12.43	16.9	3.8%	0.00%	0.00%	0.00%	0.00%

* 1% sales gain (assuming 5% profit) of export value per 10% points increases in air share

** 5% sales gain (assuming 5% profit) of export value per 10% points increases in air share

*** 10% sales gain (assuming 5% profit) of export value per 10% points increases in air share

The result of Scenario 1 without sales gain is consistent with the breakeven point analysis for carrying cost shown in Table 4-10. More usage of air shares are suggested for the industries with low BEP such as furniture manufacturing, fabricated metal product manufacturing, miscellaneous manufacturing, textile product mills, and apparel manufacturing. After taking sales gain into account, more industries such as plastics and rubber products manufacturing, machinery manufacturing, electrical equipment manufacturing, and transportation equipment manufacturing are suggested to use more air shipping. A special industry is the computer and electronic product manufacturing which is considered to have extremely high BEP in the earlier analysis. However, after considering sales gain, it is suggested to use 100 percent air shipping when every 10-percent-point increase in air share can bring 10 percent sales gain. This finding could explain why many manufacturers of electronic products like Apple and Dell prefer to use 100-percent air transport to ship their products.

To sum up, based on the concept of total cost minimization, it is suggested that the industries with low BEP should use more air shipping and those with high BEP should use less air shipping. However, this suggestion is considered to be conservative because it does not take potential sales gain into account. If considering the potential gain from reduced sales loss, the increase in transportation costs can be partly or completely offset by the increase in profit gain. A firm should pursue profit maximization rather than total cost minimization.

4.6 Conclusion

As globalization expands a firm's geographic coverage of business, it increases the bullwhip effects and inventories as well. Given that air shipping has facilitated firms' implementation of the JIT practices in the U.S., it could be replicated in global supply chains. Using the trade data and the survey data of U.S. manufacturers at the 6-digit NAICS industry level, this study examines the relationship between air share and inventory days as well as the determinants of firms' modal choice in a global supply chains. It is found that the use of air shipping in export can effectively reduce manufacturers' inventory levels at a diminishing rate. In addition, this study proposes a framework using the demand uncertainty to explain firms' choice in transportation modes in global supply chain. This study finds some support for the hypotheses that firms use faster and more expansive transportation mode for uncertain demand and slower and cheaper modes for certain demand. It is found that the demand variation contributes to more use of air shipping, while high gross margins, high cost of capital, and the relevance to timeliness facilitate firms to use air shipping to realize the demand and shorten the cash cycle. Furthermore, the industries with larger major players have higher shares of ocean shipping because of risk pooling advantages. Lastly, this study provides practical decision rules for practioners. This study uses the estimation results to project the breakeven points for carrying costs and suggest the optimal air shares. It is found that the modal decision based on total cost minimization could be too conservative. The approach of profit maximization considering potential sales gain is more complete and appropriate.

This study contributes to both the literature and practioners. For the literature, this study, to my knowledge, is the first paper that empirically examines and quantifies the relationship between transport modal and inventory levels, contributing to the inventory literature. For practitioners, this study offers practical decision guidelines for transport modal split including the breakeven points of carrying costs based on total cost minimization and optimal air shares based on profit maximization. This study makes a contribution by quantifying the decision rules using the concepts of total cost minimization and profit maximization and reiterating the importance of the latter.

This research has some research limitations. First, the study uses inventory and trade data at a 6-digit aggregate industry level. Though it is very close to the firm level, the firms in the same industry may behave and perform differently, a factor not reflected in the industry-level research. A firm-level study is encouraged to examine the findings of this study. In addition, this study uses the manufacturing data to study the relationship between air shipping in exports and the inventory level of finished goods for manufacturers. It can be extended to the retailer side studying how transportation modal section in global supply chains affects retailer's inventory holdings. Furthermore, this study can be extended to inbound logistics because the choice of transportation for imports could affect the inventory levels of raw materials.

Chapter 5 Conclusion

Globalization has become an important element in firms' operational and marketing strategies. Given that global transportation links the operations between shippers and consignees in two countries, the selection of transportation mode inevitably has a direct impact on the supply chain performance. Given that firms pursue the maximization of profit, this study asks two research questions. How do firms make transport modal decision in global supply chains? How do firms' transport modal decisions affect their operational performance? This dissertation uses two essays to address the research questions above. The first essay aims to identify and examine the factors that affect the decision of transport modal choice in global supply chains in the first essay. Furthermore, the second essay examines the effects of air shipping on manufacturing inventories.

In the first essay, the factors affecting modal decision are collected and classified into the four categories: characteristics of industry, mode, shipment, and region. Unlike the previous studies that focus on modal and shipment characteristics, this study focus on the industry characteristics and proposes that the revenue drivers and cost drivers of each industry drive the transport modal decision for exporters and importers. Using the trade data between the U.S. and 12 Asian trade partners and the survey data of U.S. manufacturers at the 3-digit NAICS industry level, this study finds that both importers and exporters use more air shipping for high-value products and when there is a positive sales surprise. Large importers and exporters have a smaller proportion of air shipping compared with small ones. While an importer's modal decision is highly associated with demand dynamics, an exporter's decision is more determined by gross margin and cost of capital but less by demand variation.

In the second essay, using the trade data of U.S. exporters and the survey data of U.S. manufacturers at the 6-digit NAICS industry level, this study examines the relationship between air share and inventory days as well as the determinants of firms' modal choice in global supply chains. This study finds that the usage of air shipping in export can effectively reduce manufacturers' inventory levels at a diminishing rate. In addition, it is found that the demand variation contributes to more use of air shipping, while high gross margins, high cost of capital, and the relevance to timeliness facilitate firms to use air shipping to realize the demand and shorten the cash cycle. The industries with larger major players have higher shares of ocean shipping because of risk pooling advantages. Furthermore, this study provides decision rules for practioners to make modal decisions in global supply chains and suggests that firms make decisions for profit maximization.

This study contributes to the literature and practioners. Academically, the previous studies consider the characteristics of mode, shipment, and region in the transport model selection. However, few studies take the revenue and cost drivers that compose the decision maker's profit in the modal decision. This study fills the gap in the FTD literature by including the profit-related factors in the model of transport modal selection. Second, most FTD studies focus on the modal split between truck and rail in a domestic market. As globalization increases the demand for international transport in global supply chains, it is important to examine the factors that affect the modal choices in an international context. This study is among the early papers that study the modal decision in an international context. Third, this study, to my knowledge, is the first paper that empirically examines and quantifies the relationship between transport modal and inventory levels, contributing to the inventory literature. For practioners, this study could inspire practioners to consider transport modal decision from a perspective of profit maximization rather than just total cost minimization. In addition, this study offers practical decision guidelines for modal split including the breakeven points of carrying costs based on total cost minimization and optimal air shares based on profit maximization and reiterates the importance of profit maximization.

There exist some research limitations as well as the opportunities for future research. First, this study uses aggregate data, which is less precise compared with disaggregate data, to estimate modal choice. The future research could collect the firm-level data to examine how the revenue and cost drivers affect their modal decisions. In addition, this study uses only U.S. manufacturer’s data for research and covers only the supply chain activities related to manufacturers. However, the wholesalers and retailers may have different decision behaviors, offering great opportunities for future research. Furthermore, the transportation links both sellers and buyers in supply chain, and the modal decision will have impact on both parties. From a systematic view, the right choice of transport mode may increase the profits of both parties. For example, air shipping which features short transit time and more frequency may decrease the bullwhip effects and lower inventory levels of both parties. The supply chain members could collaborate on the joint modal decision to maximize the overall supply chain profits. In addition, this study focuses on the relationship export modal choice and manufacturers’ finished-goods inventories. The research can be extended to inbound logistics because the choice of transportation for imports could affect the inventory levels of raw materials.

Bibliography

Bagchi, P.K., Raghunathan, T.S., Bardi, E.J., 1987. The implication of just-in-time inventory policies on carrier selection. Logistics and Transportation Review 23 (4), 373-384.

Boyer, K.D., 1977. Minimum rate regulation, modal split sensitivities and the railroad problem. Journal of Political Economy 85(3), 493-512.

Cerruti, C., 2008. The impact of offshoring on firm competitiveness. Transition Studies Review 15, 145-156.

Chen, F., Drezner, Z., Ryan, J. K., Simchi-Levi. D., 2000. Quantifying the bullwhip effect in a simple supply chain: the impact of forecasting, lead times, and information. Management Science 46(3), 436-443.

Chen, H., Frank, M., Wu, O., 2005. What actually happened to the inventories of American companies between 1981 and 2000? Management Science 51, 1015-1031.

Chen, H., Frank, M., Wu, O., 2007. US retail and wholesale inventory performance from 1981 to 2004. Manufacturing & Service Operations Management 9, 430-456.

Convention on International Civil Aviation 1944, Chicago.

Daugherty, P.J., Spencer, M.S., 1990. Just-in0time concepts: applicability to logistics / transportation. International Journal of Physical Distribution and Logistics Management 20(7), 12-18.

De Jong, G., Gunn, H.F., Walker, W., 2004. National and international freight transport models: an overview and ideas for further development. Transport Reviews 24(1), 103-124.

Dresner, M., Windle, R.J., 1992. The liberalization of U.S. international air policy: impact on the U.S. markets and carriers. Journal of the Transportation Research Forum 17(2), 273-285.

Evers, P.T., 1999. The effect of lead times on safety stock. Production and Inventory Management Journal 40(2), 6-10.

Fawcett, S.E., 1992. Strategic logistics in co-ordinated global manufacturing success. International Journal of Production Research 30(4), 1081-1099.

Friedlaender, A.F., Spady, R., 1980. A derived demand function for freight transportation. Review of Economics and Statistics 62, 432-441.

Fu, X., Oum, T.H., Zhang. A., 2010. Air transport liberalization and its impact on airline competition and air passenger traffic, Transportation Journal 49(4), 24-41.

Gaur, V., Fisher, M., Raman, A., 2005. An econometric analysis of inventory turnover performance in retail services. Management Science 51, 181-194.

Gordon, R., 1990. The Measurement of Durable Goods Prices. Chicago: University of Chicago Press.

Han, C., Dresner, M., Windle, R., 2008. Impact of global sourcing and exports on US manufacturing inventories. International Journal of Physical Distribution & Logistics Management 38, 475-494.

Harper, D.V., Goodner, K.S., 1990. Just-in-time and inbound transportation. Transportation Journal 30, 22-31.

Hayuth, Y., 1985. Freight model-split analysis of air and sea transportation. Logistics and Transportation Review 21, 389-402.

Hummels, D., 2007. Transportation costs and international trade in the second era of globalization. Journal of Economic Perspectives 21(3), 131-154.

Hummels, D., 2009. Trends in Asian trade: implications for transport infrastructure and trade costs. In: Brooks, D.H., Hummels, D. (Eds), Infrastructure's Role in Lowering Asia's Trade Costs: Building for Trade. Cheltenham: Edward Elgar.

Hummels, D., Scgaur, G., 2010. Hedging price volatility using fast transport. Journal of International Economic 82(1), 15-25.

Hummels, D., Scgaur, G., 2012. Time as a Trade Barrier. NBER Working Paper, [online] Available at:< http://www.nber.org/papers/w17758> [Accessed 25 April 2012].

IATA. 2007., Airline liberalisation. IATA Economic Briefing No 7, [online] Available at:< http://www.iata.org/SiteCollectionDocuments/890000_Airline_Liberalisation_Summary_Report.pdf > [Accessed 25 April 2012].

ICAO Secretariat., 2009. Overview of Trends and Developments in International Air Transport, [online] Available at:< http://www.icao.int/icao/en/atb/epm/Ecp/OverviewTrends.pdf> [Accessed 25 April 2012].

International Air Transport Competition Act 1979. (Serial no. 96-56), Washington, D.C.: U.S. Senate.

InterVISTAS., 2006. The economic impact of air service liberalization, [online] Available at:< http://www.intervistas.com/downloads/reports/2006-06-07_EconomicImpactOfAirServiceLiberalization_FinalReport.pdf > [Accessed 25 April 2012].

Jeffs, V.P., Hills, P.J., 1990. Determinants of modal choice in freight transport. Transportation 17, 29-47.

Kennedy, P., 2003. A Guide to Econometrics. 3rd ed. Cambridge: MIT Press.

Larson, P., 1998. Air cargo deregulation and JIT: Two 20th anniversaries in American logistics. Transportation Quarterly 52, 49-60.

Lee, H.L., Padmanabhan, V., Whang, S., 1997a. Information distortion in a supply chain: the bullwhip effect. Management Science 43 (4), 546-558.

Lee, H.L., Padmanabhan, V., Whang, S., 1997b. The bullwhip effect in supply chains. Sloan Management Review 38 (3), 93-102.

Levin, R.C., 1978. Allocation in surface freight transportation: does rate regulation matter? Bell Journal of Economics 12(1), 18-45.

Levy, D.L., 1995. International sourcing and supply chain stability. Journal of International Business Studies 26, 343-360.

Levy, D.L., 1997. Lean production in an international supply chain. Sloan Management Review 38(2), 94-102.

Lieb, R.C., Millen, R.A., 1990. The responses of general commodity motor carriers to just-in-time manufacturing programs. Transportation Journal 30, 5-11.

Marlin, P.L., 1995. Competition in European aviation: pricing policy and market structure. The Journal of Industrial Economics 43(2), 141-159.

Maillebiau, E., Hansen, M., 1995. Demand and consumer welfare impacts of international airline liberalization: the case of the North Atlantic. Journal of Transport Economic and Policy 29(2), 115-136.

Melville, J.A., 1998. Identifying the regulatory effect of bilateral agreements on international aviation. Journal of Air Transport Management 4, 39-46.

Nahmias, S., 1997. Production and Operations Analysis. 3rd ed. Burr Ridge:Irwin/NcGraw-Hill.

Ohno, T., 1988., The Toyota Production System: Beyond Large-Scale Production. Portland:Productivity Press.

Oum, T.H., 1979., A cross-sectional study of freight transportation and inter-modal competition in Canada. Bell Journal of Economics 10(2), 463-482.

Oum, T.H., 1998., Overview of regulatory changes in international air transport and Asian strategies towards the US open skies initiatives. Journal of Air Transport Management 4, 127-134.

Rajagopalan, S., Malhotra, A., 2001. Have U.S. manufacturing inventories really decreased? An empirical study. Manufacturing & Service Operations Management 3, 14-24.

Regan, A., Garrido, R.A., 2002. Modeling freight demand and shipper behavior: state of the art, future directions. In: Hensher, D. (Ed.), The Leading Edge of Travel Behaviour Research. Oxford:Pergamon Press.

Richardson, H., 1995. Control your costs then cut them. Transportation & Distribution, December 1, 1995.

Robyn, D., Reitzes, J., Moselle, B., 2002. Beyond open skies: the economic impact of a US-EU open aviation area. Washington, D.C.:Brattle Group.

Rumyantsev, S., Netessine, S., 2007. What can be learned from classical inventory models? A cross-industry exploratory investigation. Manufacturing & Service Operations Management 9(4), 409-429.

Shah, R., Shin, H., 2007. Relationships among information technology, inventory, and profitability: an investigation of level invariance using sector level data. Journal of Operations Management 25, 768-784.

Su, S.I., Ke, J.Y., Lam, P. , 2011. The development of transportation and logistics in Asia: an overview. Transportation Journal 50(1), 124-136.

Tersine, R.J., 1994. Principles of Inventory and Materials Management. 4th ed. Upper Saddle River:PTR Prentice-Hall.

Trent, R.J., and R.M. Monczka. 2003. Understanding integrated global sourcing. International Journal of Physical Distribution & Logistics Management 33(7), 607-629.

Winston, C., 1981. A disaggregate model of the demand for intercity freight transportation. Econometrica 49(4), 981-1006.

Winston, C., 1983. The demand for freight transportation: models and applications. Transportation Research Part A 17(6), 419-427.

Wooldridge, J.M., 2003. Introductory Econometrics: A Modern Approach. 2nd ed. Boston:South-Western College.

Yeaple, S.R., 2006. Offshoring, foreign direct investment, and the structure of US trade, Journal of the European Economic Association 4(2-3), 602-611.

Zlatoper, T.J., Austrian, Z., 1989. Freight transportation demand: a survey of recent econometric studies. Transportation 16, 27-46.