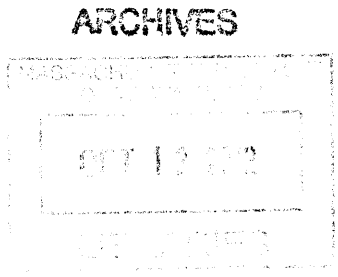
Evolution of US Air Cargo Productivity



by

David J. Donatelli

B.S. Naval Architecture and Marine Engineering
Webb Institute, 2011

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Signature of Author: .....
Department of Civil and Environmental Engineering
August 10, 2012

Certified by: .....
Peter P. Belobaba
Principal Research Scientist of Aeronautics and Astronautics
Thesis Supervisor

Accepted by: .....
Heidi M. Nepf
Chair, Departmental Committee for Graduate Students

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David J. Donatelli

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ABSTRACT

This thesis provides an overview of the US air cargo industry since airline deregulation in 1978, including a brief overview of the historical evolution of air cargo transport in the US from the early 1900s until the late 1970s and a discussion about the major international factors affecting global air cargo. A deeper analysis of the US air cargo industry follows these background discussions, emphasizing the growth of all-cargo carrier traffic in the past 30 years while noting the decline of combination carrier traffic within the past decade. Furthermore, operating cost analyses for the past 20 years reveal that major improvements in labor productivity have helped all-cargo carriers and combination carriers decrease unit costs, even while the price of fuel has risen dramatically.

Productivity of US air cargo carriers is explored from 1990 to 2010 through two types of metrics, single-factor productivity (SFP) and multi-factor productivity (MFP). SFP metrics measure an airline's ability to turn inputs, such as fuel, labor, and capital, into outputs, such as available ton-miles (ATMs) and revenue ton-miles (RTMs). The MFP metric presented measures how effectively an airline produces an output from multiple inputs, essentially combining the SFP metrics.

Single-factor productivity results show that the US air cargo industry has made significant improvements in labor productivity and capital productivity, with minor improvements in fuel productivity. FedEx and UPS have achieved the smallest improvements over the past 20 years, while other all-cargo carriers and combination carriers realized substantial advancements in the past two decades. Multi-factor productivity results echo the SFP results. Over the past 20 years, FedEx and UPS improved MFP 18%, combination carriers became approximately twice as productive, and the other all-cargo carriers increased MFP dramatically. However, questionable data reported by all-cargo carriers and methods used to determine only cargo-related data for combination carriers limit the accuracy of these results and caused difficulties calculating productivity throughout this thesis.

Thesis Supervisor: Peter P. Belobaba
Title: Principal Research Scientist of Aeronautics and Astronautics

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NOMENCLATURE

Aircraft Utilization	-	Block hours flown per day per aircraft
All-Cargo Carrier	-	Airline that transports only cargo
ATM or ATK	-	Available ton-mile or available ton-kilometer, the available weight capacity multiplied by the transport distance
Block Hour	-	Time between gate departure and gate arrival
BTS	-	Bureau of Transportation Statistics
Combination Carrier	-	Airline that transports passengers and cargo
DOT	-	Department of Transportation
FTE	-	Full-time equivalent employee
ICAO	-	International Civil Aviation Organization
Integrator	-	Company combining all operations of freight shipping into one business, including trucking, freight forwarding, and air transport
LF	-	Load factor, the ratio of RTMs to ATMs or RTKs or ATKs
MFP	-	Multi-factor productivity
RTM or RTK	-	Revenue ton-mile or revenue ton-kilometer, the weight of cargo carried multiplied by the transport distance
SFP	-	Single-factor productivity
ULD	-	Unit load device, standardized container used for cargo stowage

1. INTRODUCTION AND OBJECTIVES

The US air cargo industry first emerged in the mid-1900s, but significant growth was delayed until after the Airline Deregulation Act of 1978 and the Motor Carrier Act of 1980 removed limitations on the air cargo industry, such as the amount of cargo an airplane could transport or the proximity to airports where cargo could be delivered. Two types of airlines compose the air cargo industry, all-cargo carriers and combination carriers. Combination carriers are airlines that operate both passenger services and cargo services while all-cargo carriers perform only cargo services. Furthermore, within the all-cargo carrier classification, integrated freight companies, such as FedEx and UPS, carry their own distinction by operating all functions related to cargo shipping – trucking, freight forwarding, and air transportation – whereas other all-cargo carriers only provide air transportation.

A primary objective of this thesis is to provide an overview of the US air cargo industry since airline deregulation. In Chapter 2, we present a brief overview of the historical evolution of air cargo transport in the US from the early 1900s until the late 1970s and a global air cargo discussion about the major international factors affecting air cargo to provide a context for analyses of the US air cargo industry. The second half of Chapter 2 comprises a deeper analysis of the US air cargo industry, emphasizing the growth of all-cargo carrier traffic in the past 30 years while noting the decline of combination carrier traffic within the past decade. Furthermore, analyses of operating cost for US cargo carriers throughout the past 20 years concludes Chapter 2, revealing that major improvements in labor productivity have helped all-cargo carriers and combination carriers decrease unit costs, even while the price of fuel has risen dramatically in the past decade.

The second objective of this thesis is to assess the evolution of productivity for the US air cargo industry. Chapter 3 explains the available data used in this thesis and presents the methodology used for the productivity analyses. Two types of metrics are presented in the methodology to explore productivity of US cargo carriers: single-factor productivity (SFP) and multi-factor productivity (MFP). SFP metrics measure an airline's ability to turn inputs, such as fuel, labor, and capital, into outputs, such as available ton-miles (ATMs) and revenue ton-miles (RTMs). The MFP metric presented in this thesis measures how effectively an airline produces an output from multiple inputs, essentially combining the SFP metrics.

Chapter 4 shows the productivity results beginning with single-factor metrics and concluding with multi-factor metrics. Single-factor productivity results show that the US air cargo industry has made significant improvements in labor productivity and capital productivity, with minor improvements in fuel productivity. FedEx and UPS have achieved the smallest improvements over the past 20 years, while other all-cargo carriers and combination carriers realized substantial advancements in the past two decades. Multi-factor productivity results echo the SFP results. Over the past 20 years, FedEx and UPS improved MFP 18%, combination carriers became approximately twice as productive, and the other all-cargo carriers increased MFP dramatically. However, it is important to note that questionable data reported by all-cargo carriers and methods used to determine only cargo-related data for combination carriers limit the accuracy of these results and caused difficulties calculating productivity throughout this thesis.

Chapter 5 concludes the thesis and provides a brief summary of each chapter. Major trends in the US air cargo traffic and operating costs during the past two decades are reiterated. Additionally, key productivity results are re-emphasized with special attention given to the driving factors of the change and evolution realized since 1990.

2. US AIR CARGO INDUSTRY BACKGROUND

This chapter describes the evolution of the US air cargo industry. The first section highlights historical events during the growth of the air cargo industry from the first recorded air cargo flight in the US to deregulation of the airline industry in 1978. After a historical context is provided, the next section discusses the establishment and growth of integrated freight companies, FedEx and UPS. Air cargo operations are then described in the third section, with separate descriptions for combination carriers, airlines that carry cargo and passengers, and all-cargo carriers, airlines that operate only freight aircraft without scheduled passenger service. At the end of this chapter, recent air cargo industry trends are presented. A brief review of the global air cargo industry provides context for a more in-depth analysis of the US air cargo industry.

2.1 HISTORICAL BEGINNINGS

A commonly accepted first recording of air cargo transport occurred in the United States of America on November 7, 1910. The flight departed from Dayton, Ohio with several rolls of fabric on board, and arrived in Columbus, Ohio 61 minutes later to deliver the fabric (Allaz, 22). However, the use of airplanes to transport cargo remained limited prior to World War I, even though there are a few documented flights throughout Europe between 1910 and 1914, transporting small items such as lamps, tobacco products, newspapers, and mail.

World War I (WWI) sparked rapid growth of and development of airplane technology. While most developments were intended for tactical purposes, militaries soon put aircraft to use carrying mail and supplies. Allaz notes in his book, *The History of Air Cargo and Airmail from the 18th Century*, that, "the regular and speedy forwarding of mail is one of the surest means of

maintaining the determination of the troops. It was therefore hardly surprising that the military leaders very soon had the idea of using air transport to speed up postal services to their armies" (36). The post-WWI era in the USA was marked by vast expansion of airmail services, the transport of post/mail via airplanes.

US Domestic airmail service was explored during WWI, but the first service was not initiated until 1918. At the request of Congress, the US Postmaster General teamed with the US Army and established a route between New York City and Washington DC – a contractual agreement where the Army flew mail between the cities at the expense of the US Post Office. The next eight years saw transcontinental growth of the US airmail network, and by 1926 post was being transported across the network shown in Figure 1. Privatization of the US airmail network also occurred in 1926, and several companies signed contracts with the US Post Office to fly mail along various sectors of the network shown in Figure 1.

In 1930, the US Postmaster General opted not to renew the contract agreements with all of the private companies. Instead, nearly all of the mail was contracted to be carried by three groups: General Motors North Aviation Group (with Transwestern Air Express), United Aircraft and Transport Corporation (subsidiaries of United Airlines), and Aviation Corporation of Delaware (American Airways). These agreements were executed in a questionable manner, with the contracts being favored towards companies with large financial backings during secretive meetings. These questionable contracts cost the US Postal Office approximately $56 million over five years, prompting President Roosevelt to rescind these contracts and restructure the US airmail network – forming the foundations of regulation in the air industry. The Airmail Act of 1934 allowed the US Post Office to negotiate their own contracts for airmail service, but postal

rates and remuneration were specified by the Interstate Commerce Commission. The result was cheaper airmail service with greater outreach throughout the US. (Allaz, 66-67)

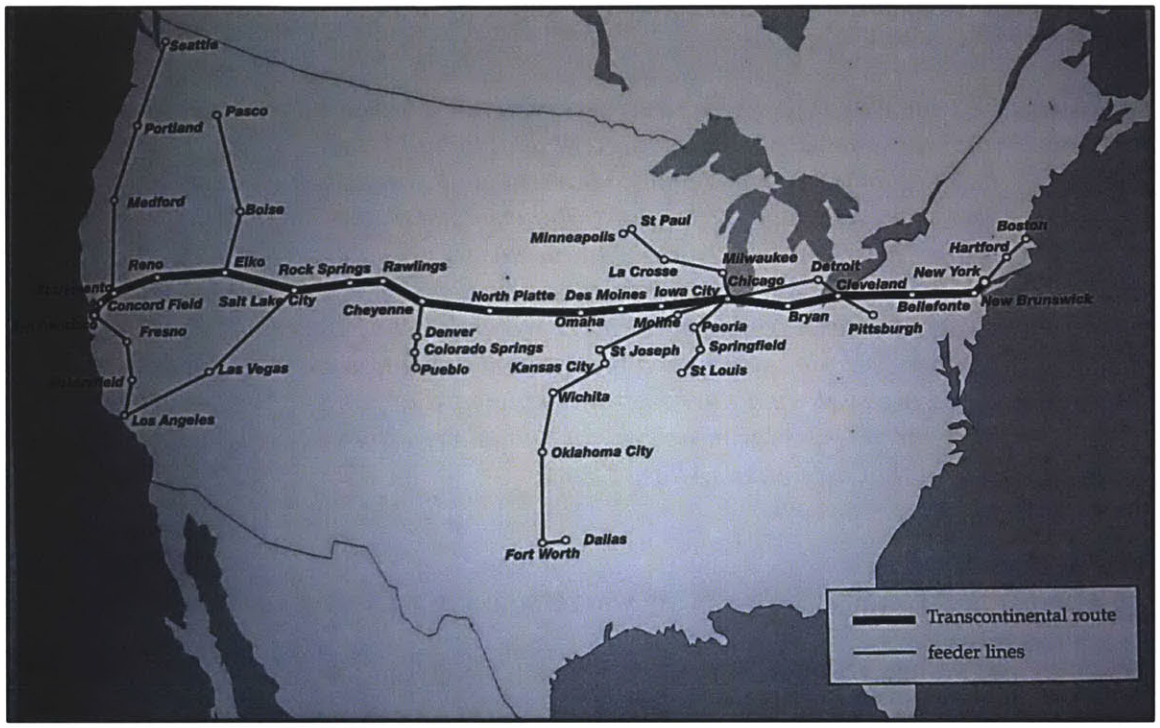

Figure 1. US Post Office Airmail Network, 1926

Source: The History of Air Cargo and Airmail (Allaz, 65)

World War II marked a switch in the utilization of aircraft for transport purposes. During the war, airlifts became popular and significant in carrying out strategic operations. As reported by Allaz, aircraft were used to fulfill "all the needs of a fighting force, in terms of men, armaments and munitions, supplies and even fuel…Supply by air had become a major component of logistics and the art of war"(151). Furthermore, commercial air cargo transport began to expand during the war when American Airlines, United Airlines, Transwestern Airlines (TWA), and Eastern Airlines founded a research group named Air Cargo Inc. to explore the future of air freight. Even though airlifts were instrumental to the war efforts, they paved the way for a revolution in commercial air cargo services – the introduction of dedicated airfreight

flights in the US. However, air freight would not take off until experienced and dedicated pilots returned from the war. John F. Kennedy may have summed up this scenario best when he wrote a letter to the Air Transportation Association of America, writing:

It was in World War II that air cargo was really developed on a large scale, and the young men who are now veterans suffered a great deal to build it up. Unfortunately, a lot of the top officials in the established airlines did not have to go through such an experience, or, if they did, it did not affect them very much, and many of them appear to be managing their companies as they did before the war, when air transportation was largely a matter of passengers and mail and a few packages in the luggage compartments... The fact that these veterans' companies, even without operating certificates, already carry more freight than do the established lines, which are members of your association, is to me a pretty good indication a) that they want to go into this new activity on a big scale and have been working hard to pioneer this new business, and b) that your members, who possess far more capital and other resources have been making only half-hearted efforts in that direction. (Allaz, 176)

Some of the veterans who Kennedy was referencing were the founder and pilots of the National Skyway Freight Corporation (NSFC), which would later be known as the Flying Tiger Line Inc. These men were members of the Flying Tigers group who volunteered to fight the Japanese invasion of South China in 1941. NSFC was founded in 1945 with a fleet of 14 Budd-RB1 aircraft. Their first business included transporting fresh produce, grapes, from Bakersfield, California to Atlanta, Georgia. Soon they expanded their service to include carriage of items such as flowers, furniture, and animals. However, all of these flights were chartered because NSFC was not authorized by the Central Aeronautics Board (CAB) to operate scheduled flights, making it difficult for NSFC to survive competition with the major passenger airlines. (Allaz, 179)

Operations turned around when NSFC officially changed its name to the Flying Tiger Lines Inc., in 1947, and when they were authorized to begin operating scheduled flights, starting with a service from Los Angeles, California to New York City in 1949. When the US began

involvement in the Korean War in 1950, the US government called upon the Flying Tiger Lines to perform airlifts to supply the ground troops. These opportunities aided growth and expansion of Flying Tiger Lines. Over the next two decades, Flying Tiger Lines grew to become the largest US dedicated-freight carrier, operating domestic flights in the US and an extensive international freight network. (Allaz, 180)

While no major overhauls of the US air cargo industry occurred during the 1950s and 1960s, there were noticeable changes in operations. The 1960s saw the advent and implementation of containers for air transport. The use of standardized containers facilitates easy handling at freight facilities because the size and shape of containers are consistent throughout the industry. Furthermore, standardized containers simplify intermodal transportation for similar reasons; operators of rail or truck services know what type of package to expect before it arrives. The other significant change in operations was the growth of international air cargo traffic from 1950 to 1970, as shown in Table 1. This table includes global data, but it is still clear that international air cargo traffic grew faster than domestic air cargo traffic, signifying a shifting focus away from domestic mail/express towards international freight. However, as integrated freight companies emerged in the air cargo industry during the late 1970s and early 1980s, and airline regulations were repealed in 1978, a shift back toward mail and express occurred.

Table 1. International and Domestic Air Cargo Traffic Growth

Years	International	% Total	Domestic	% Total	Total
1950	265	34	505	66	770
1955	440	35	800	65	1,240
1960	930	46	1,110	54	2,040
1965	2,500	52	2,300	48	4,800
1970	6,430	61	4,100	39	10,560

Source: Adapted from *The History of Air Cargo and Airmail* (Allaz, 221)

2.2 INTEGRATOR EVOLUTION

As the air cargo industry began growing rapidly in the 1970s, a niche market developed for integrated freight companies. An integrated freight company, or integrator, combines all operations of freight shipping into one business, including road carriage, freight forwarding and air transport. This section describes the founding and growth of the two major US integrated freight companies, FedEx and UPS, highlighting their rapid expansion within the US followed by their globalization. Further discussion focuses on some particulars of FedEx's and UPS' business operations, including fleet and labor characteristics.

2.2.1 Federal Express

Fred Smith founded FedEx corp. as Federal Express in 1971, located in Little Rock, Arkansas. FedEx relocated to its current hub, Memphis, Tennessee, in 1973, beginning operations in April. According to Allaz, FedEx's initial operations are characterized by three aspects: implementing a hub-and-spoke network, controlling all facets of the express shipping process (ground and air), and limiting parcel size and weight (272). None of these ideas was groundbreaking alone, but Smith revolutionized the air cargo industry, specifically express, by combining these principles into one operation.

Establishing a hub-and-spoke network structure in the air freight industry allowed FedEx to consolidate cargo handling at one location and to eliminate reliance on passenger carrier schedules for freight shipping. These changes reduced the cost of operations and enabled expedient, reliable service. The crux of this operation is maintaining a service schedule by which aircraft depart from cities around the US, carrying express mail and packages, and

converge on the Memphis hub at night. The cargo is sorted at the Memphis facility overnight, loaded onto aircraft for delivery throughout the US, with departures in the early morning. The flights arrive at the destination airport and depart to the final destination on a distribution network of FedEx ground trucks by the late afternoon.

This practice results in lower aircraft utilization compared to US passenger aircraft. Utilization is defined as block hours per day, where block hours is the time spent in the aircraft from gate departure to gate arrival. For US passenger airlines, aircraft utilization can be upwards of 10.5 hours per day (Belobaba, 147). Table 2 shows aircraft utilization numbers for FedEx operations, with a fleet average of 3.3 hours per day. Even though FedEx's fleet has lower utilization compared to US passenger airlines, express operations often return high yields, where yield is defined as a measure of revenue per kilometer, or mile, that the cargo is transported. Furthermore, most aircraft purchased by freight companies are converted passenger aircraft with very low capital costs. These two operational characteristics of express operations, low utilization with high yields, produce a sustainable business.

Table 2. Federal Express Fleet Utilization

Aircraft	**Utilization (Hours/day)**
Cessna 208	1.0
B727-200F	2.2
Airbus A310	2.7
Airbus A300B4-600	4.2
B757-200F	2.8
DC10-10F	4.9
DC10-30F	6.6
MD11F	9.7
Total	**3.3**

Source: Adapted from *Moving Boxes By Air* (Morrell, 252)

Maintaining a strict service schedule requires total control of all processes, the second characterizing aspect of FedEx's operations. Realizing this aspect established what now is known commonly as an integrated freight company. Allaz describes FedEx's operations and defines the essence of an integrated freight company, saying, "Federal Express carries out all these operations [road carriers, freight forwarders, airlines] itself, whether on the ground or in the air. It integrates all the means and all the operations of transportation: it is an integrator" (273). Possessing such control over the shipping process led FedEx to add to their basic operational principles. As FedEx has evolved, service has expanded to include: door-to-door service, where all aspects of shipping are covered by the shipper, money-back, time-definite guarantees, and shipment tracking, which reinforces the transparency and reliability of service.

The inaugural operations connected 25 U.S. cities using 14 Dassault Falcon aircraft to deliver 186 packages (FedEx). This network did not expand much during the next decade because of limitations imposed by regulations of the US air industry. Such regulations limited the payload size of aircraft that FedEx could operate to 7500 pounds, while the outreach of FedEx ground operations was limited to a 25-50 mile radius around the airports by the road transport regulations (Allaz, 274). The Airline Deregulation Act of 1978, and the subsequent Motor Carrier Act of 1980, removed many of these limitations on FedEx's services, facilitating the expansion of FedEx's express network, and express operations in general.

Shortly following deregulation, FedEx purchased a fleet of seven B727-100Fs, and began initiatives to include international service. In 1981, FedEx began international operations by adding Canadian routes to their existing hub-and-spoke network. Later, in 1985, FedEx expanded to Europe by opening operations in Brussels, Belgium, via London. The major event that launched FedEx into international markets was the 1989 acquisition of the established

international carrier, Flying Tiger Lines. At the same time, a regional hub was opened in Anchorage, Alaska, which served as a gateway to the Asian/Pacific hub in Subic Bay, Philippines in 1995. FedEx continued to grow their Pacific operations while European services remained limited. However, in 1999, FedEx established a hub at Paris Charles de Gaulle Airport, expanding their services in Europe.

More current expansion for FedEx includes an agreement with the United States Postal Service (USPS) in 2000, wherein FedEx agreed to "provide domestic air transport services to [USPS], including its first-class, priority and express mail...and provides transportation and delivery for [USPS's] international delivery service called 'Global Express Guaranteed'" (Morrell, 250). In return for providing these services, USPS allows FedEx to install drop boxes at post offices throughout the US. Most recently, FedEx has repositioned their Asian hub strategically as international trade patterns have converged around China and the Middle East; in 2009, FedEx closed the Subic Bay hub and opened a new hub at Guangzhou Baiyun International Airport in China.

2.2.2 United Parcel Service

United Parcel Service (UPS) was founded in Seattle, Washington in 1907 as a parcel transportation company utilizing truck routes along the US west coast. Even though UPS was founded with a focus on ground transportation, they pushed the frontier of air freight transportation. As stated on UPS's website, "in 1929 UPS became the first package delivery company to provide air service via privately operated airlines" (UPS). However, the timing of this service coincided with the start of the US great depression, resulting in less-than-favorable

traffic volume and an unsustainable business; the air service quickly was cut from UPS's operations.

However, with FedEx leading the express explosion in the wake of deregulation, coupled with prevalent globalization in the late 1970s and 1980s, UPS expanded their services to include air freight again. The first UPS airplane was purchased in 1981, and UPS's hub in Louisville, Kentucky was established in 1982. International service was established in 1985 with European countries when a hub was established in Cologne, Germany. By 1990, UPS had established their Worldwide Express Service offering trade originating in 104 countries and destined for 175 countries (UPS).

The next significant move by UPS was the acquisition of the air freight company Challenge Air in 1999. Challenge Air had an established trade network between the US and Latin and South America, including 17 cities in 13 countries, all of which were turned over to UPS in the acquisition (Morrell 106). Additionally, UPS began trading publicly on the New York Stock Exchange in 1999. This move allowed UPS "to make strategic acquisitions in important markets around the world" (UPS). Since this public offering, UPS purchased Lynx Express in 2005, an established UK airline, and opened a hub at Shanghai's Pudong Airport in 2009.

It is also important to note that most UPS employees are unionized. This is a significant difference between UPS and FedEx. The majority of FedEx employees remain un-unionized with the exception of the pilots. FedEx employees have attempted unionization multiple times, but, so far, all have been unsuccessful.

2.3 OPERATIONAL CHARACTERISTICS OF AIR CARGO OPERATORS

Given a historical understanding of the development of the US air cargo industry, it is important to highlight the major types of players in the air cargo industry. Two distinct categories of airlines operate in the air cargo industry, combination carriers and all-cargo carriers. This section presents the operational characteristics of each type of cargo carrier, describing the typical business approach for airlines in each category, typical aircraft operations, and cargo handling techniques.

2.3.1 Combination Carriers

A strict definition of a combination aircraft is a "multi-compartment aircraft configured for purposes of transporting passengers and freight together on the main deck" (Morrell 144). However, for this thesis, the definition of a combination carrier is broadened to include any airline that carries cargo and passengers, in any configuration. Most frequently, cargo is carried on long-haul passenger flights of large network carriers because of the extra payload capacity available in the large belly-holds of long-haul, wide-bodied aircraft, compared to the smaller belly-holds of narrow-bodied aircraft. For example, Morrell cites that the available cargo payload for an Airbus A320, a narrow-bodied aircraft, is 1.0 tonne, and the available cargo payload for a Boeing B747-400, a wide-bodied aircraft, is 20.0 tonne (132). The reduced available payload on narrow-bodied aircraft is a main reason that low-cost carriers (LCCs) have limited, or refused to carry, cargo on their passenger flights. Another method that a combination carrier may use to transport cargo is using freight-only aircraft that they operate. Since the global recession in 2008, many combination carriers decreased their dedicated freighter operations; all major US passenger carriers have since completely cut their all-freighter operations. Morrell describes this response saying that combination carriers will, "downsize

[freighter operations] at times of a major drop in demand (as occurred at the end of 2008). Given that cargo capacity on passenger and combi flights is a by-product of the passenger services the axe tends to fall on their freighter flights" (74).

Combination carriers face an interesting difficulty when deciding how much, or which, cargo to accept. Often, the exact number of passengers onboard an aircraft is variable until the plane is loaded, because of no-show and stand-by passengers. This uncertainty makes it difficult to plan for the exact amount of cargo that can be loaded. Not only do passengers add weight on the plane, but their baggage consumes volume in the cargo hold. This means that decisions regarding cargo usually are made last minute. However, to mitigate any uncertainty, the available cargo capacity typically is limited when an airline plans to carry cargo by assuming that the plane will reach 100% passenger capacity, providing a conservative estimate of cargo payload. If fewer passengers arrive at the time of the flight, this conservative estimate allows extra cargo to be loaded and transported.

2.3.2 All-Cargo Carriers

The classification of all-cargo carriers used in this thesis includes integrated freight carriers, such as FedEx and UPS, and dedicated freight carriers – airlines that operate only freight aircraft with no scheduled passenger service. A significant feature of all-cargo airlines is the aircraft that they operate. Most freight aircraft are converted passenger aircraft; the seats are removed, the structure is enhanced to handle increased payload, a large cargo hatch is installed, and rollers are installed to slide cargo containers and pallets into the aircraft. Converting passenger aircraft has both pros and cons compared to purchasing new freight aircraft. On the positive side, converting a passenger aircraft requires minimal capital expenditures, which works

well in low-utilization, short-haul operations, as conducted by most integrated freight carriers (Morrell, 135). However, a converted aircraft typically is older and has higher fuel consumption, thus fuel costs, and maintenance costs than a new freight aircraft. Therefore, a new freight aircraft would be more suitable for long-haul flights, such as intercontinental trade between US, Europe, and Asia.

Freight forwarders are a crucial component of freight operations for all-cargo airlines. As defined by Morrell, "a freight forwarder is an intermediary who acts on behalf of importers, exporters or other companies or persons involved in shipping goods, organizing the safe, efficient and cost-effective transportation of goods" (109). Essentially, the freight forwarder is the middle-man who communicates between the shipper, the airline, and the consignee (receiver of goods). Typically, the freight forwarder is responsible for transporting the freight from the shipper to the airline and from the airline to the consignee. This transportation can be accomplished if the freight forwarder operates its own truck service, or by hiring third-party trucking companies to transport the freight. Integrated freight companies take on the role of the freight forwarder and the airline, thus assuming all responsibility for the cargo from pick-up to delivery.

With such a great variety in how cargo is managed pre- and post-flight, a desire developed among shippers and transportation companies for standardization in cargo packaging. Standardized containers, or unit load devices (ULDs), resolved this issue in the air cargo industry. ULDs allow the freight forwarder or airline to combine packages into a single container, improving the volume utilization of cargo capacity on the aircraft; certain containers are designed to fit the curvature of the aircraft. The standardized design of the ULDs allows commonality across cargo handling facilities, expediting and simplifying services. Integrated

carriers often develop their own form of standardized containers that best suits their operations, allowing for easy and quick package sorting at hub facilities. Even though containers have streamlined the shipping process and facilitated intermodal shipping, there still are negative impacts of containerized cargo. For instance, handling difficulties may arise if cargos heading to different destinations are packaged in the same ULD. This will increase the number of ULD movements at handling facilities and slow delivery time, which is an important factor in air cargo transport. Furthermore, additional storage space is required at cargo handling facilities to store containers before they are filled or while they are waiting to be transported.

2.4 RECENT INDUSTRY TRENDS

This section presents a more quantitative analysis of the air cargo industry in recent years. Global air cargo trends are discussed briefly to provide context for an in-depth discussion of the US air cargo industry. As discussed in the previous section, distinct operational differences between all-cargo and combination carriers provide sound reason to separate the US air cargo industry analysis into two parts, one focusing on all-cargo carriers and the other focusing on combination carriers. Within each of these analyses, cargo traffic trends are discussed for the period from 1983 to 2010. Furthermore, each analysis includes descriptions of operating expenses from 1990 to 2010.

2.4.1 Overview

The air cargo industry truly is a global industry, and thus it is susceptible to variations in global economics. Previous analyses suggest that the air cargo industry grows proportionally with GDP at a factor in the range of 2-2.5 (Morrell). Throughout the past decade, a flurry of international events precipitated change throughout the air cargo industry. The major trends in

the industry are explored in this section by analyzing traffic figures in terms of revenue ton-kilometers (RTKs), available ton-kilometers (ATKs), and average load factor (LF). Load factor is defined as the proportion of available payload (weight) carried, and it is calculated by dividing RTKs by ATKs. This metric does not capture the volume or shape of cargo carried, which is an important issue in managing cargo operations while loading an aircraft. However, standardized container units often are used on large freighter aircraft, and customers typically pay on a per-container basis. This deemphasizes cargo volume issues for a large fraction of traffic, and supports the use of a load factor metric based on payload.

Air cargo traffic varies depending on region throughout the world. For example, there is much more traffic, in terms of RTKs, on routes from Asia to Europe or to North America than there is on routes from North America to South America or from Australia to Asia. The global distribution of RTKs in 2009 is provided in Figure 2. The two busiest trade lanes exist between Asia and Europe, and Asia and North America, at 26.9% and 20.1% of total world air cargo RTKs. Another large trade lane of note occurs between Europe and North America, claiming 13.7% of total RTKs.

For this thesis, focus primarily will be on US carrier air cargo traffic with sufficient global analyses to provide an international context. Recent international air cargo traffic evolutions will be discussed briefly followed by a more in-depth discussion of traffic and financial trends for US carriers.

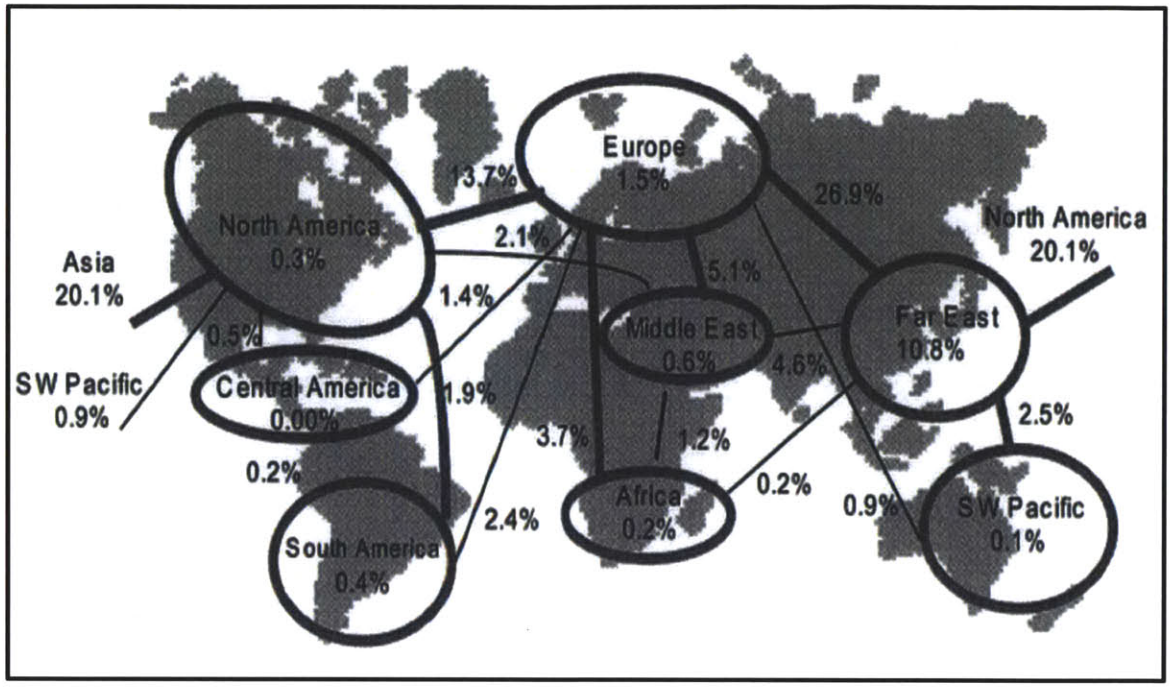

Figure 2. Distribution of Global Traffic

Source: *Moving Boxes by Air*

2.4.2 Global Trends

The global air cargo industry appeared to be surging at the turn of the century, however, the dot-com bubble collapse, followed by the September 11th terror attacks, hurt the industry in terms of the RTKs flown. Figure 3 shows the trends in global traffic during the past decade, including RTKs and LF. RTKs rise from 2001 into the middle of the decade. Additionally, load factor increases two percent from 2001 to 2002, indicating that RTK traffic is growing faster than available capacity, emphasized by cargo carriers' restraining capacity, as described in Seabury's March 2011 State of the Industry presentation (21). This rebound seen in load factor following 2001 indicates the air cargo industry's ability to rebound strongly from the economic recession and terrorist attacks in the early 2000s.

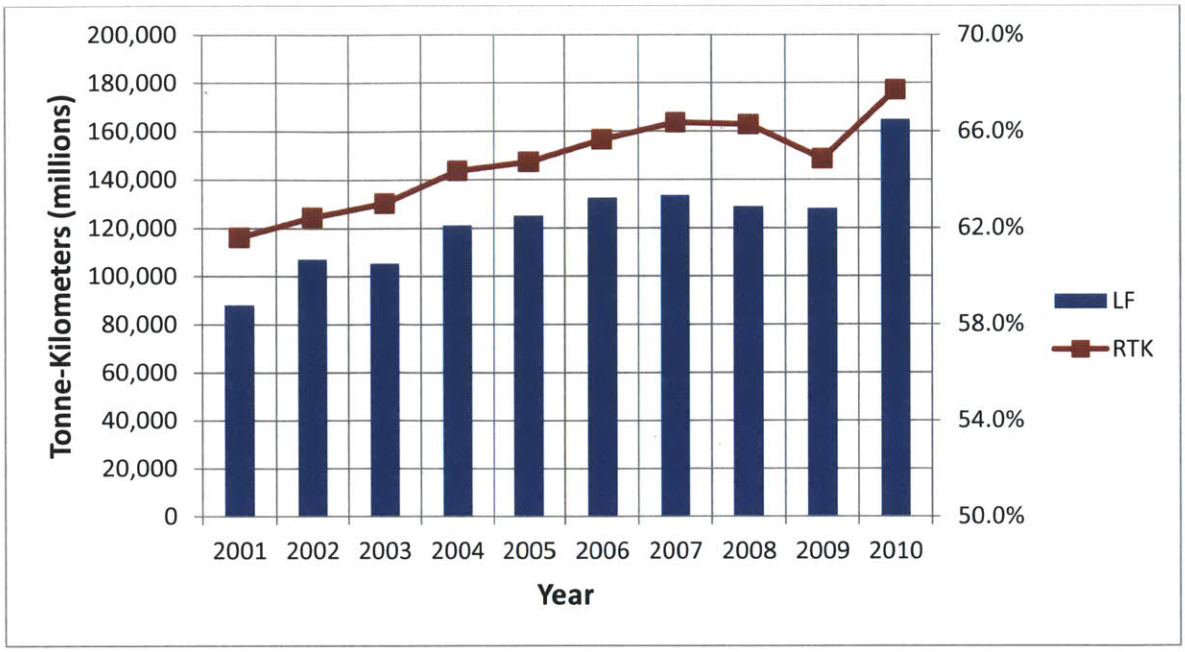

Figure 3. Scheduled Global Air Traffic

Source: ICAO Air Transport Reporting Form A

Growth was steady in the industry throughout the mid-2000s. RTKs grew from 31% from 2002 to 2007, while load factor increased from 60.7% in 2002 to 63.3% in 2007. A lot of this growth can be attributed to the emerging economies of the East. Notably, China and the UAE experienced rapid economic growth, demanding exports, which fed the entire global cargo industry. However, when the US financial crisis occurred in 2008, leading to the global recession in 2009, the entire air cargo industry receded. The industry experienced a minor decline in RTKs, and a noticeable drop in revenues was realized, as shown in Figure 4. Similar to events of the early 2000s, the repercussions of this recession were more prevalent in the US trade than in global trade; this will be discussed in further detail in the next section. The ability of the industry to limit capacity growth in 2010 allowed RTKs to increase faster than available capacity following the recession. Peter Conway highlights this point in the October 2010 issue of *Airline Business*, stating, "In the first half [of 2010] IATA shows capacity consistently

growing only half as much as traffic in all global markets" (49). This action by airlines caused load factor to surge in 2010, indicating the possibility of a strong and quick recovery out of the recession.

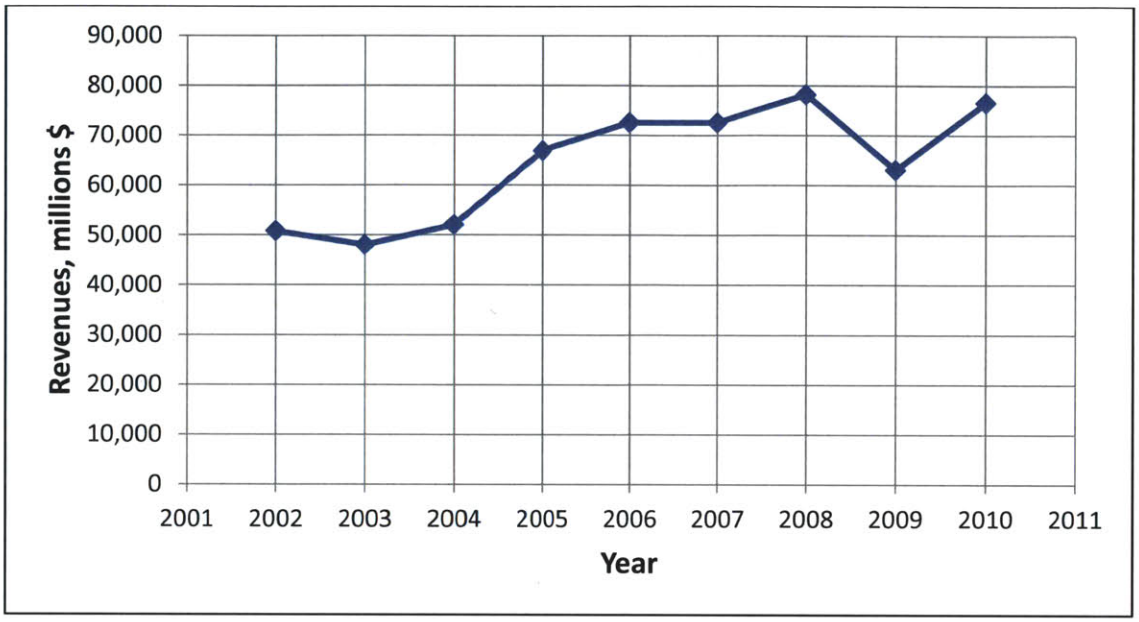

Figure 4. Global Air Cargo Revenues

Source: *Airline Business*

The top 20 world air cargo carriers ranked by RTKs, shown in Figure 5, seemingly are split into three distinctive tiers. The top tier contains only integrated freight companies, FedEx and UPS, carrying approximately 16 billion and 13 billion RTKs respectively. The second tier consists of established carriers, with great representation from large combination carriers, such as Cathay Pacific, Lufthansa, Air France-KLM, and Emirates. These carriers operate in the region of seven to 10 billion RTKs per year. The third tier of carriers represents a mix of booming air cargo carriers and combination carriers whose cargo operations may be waning. Some of the booming carriers are Air China, Qatar Airways, and China Southern Airlines, while Delta Airlines, British Airways, and American Airlines represent carriers with declining traffic figures.

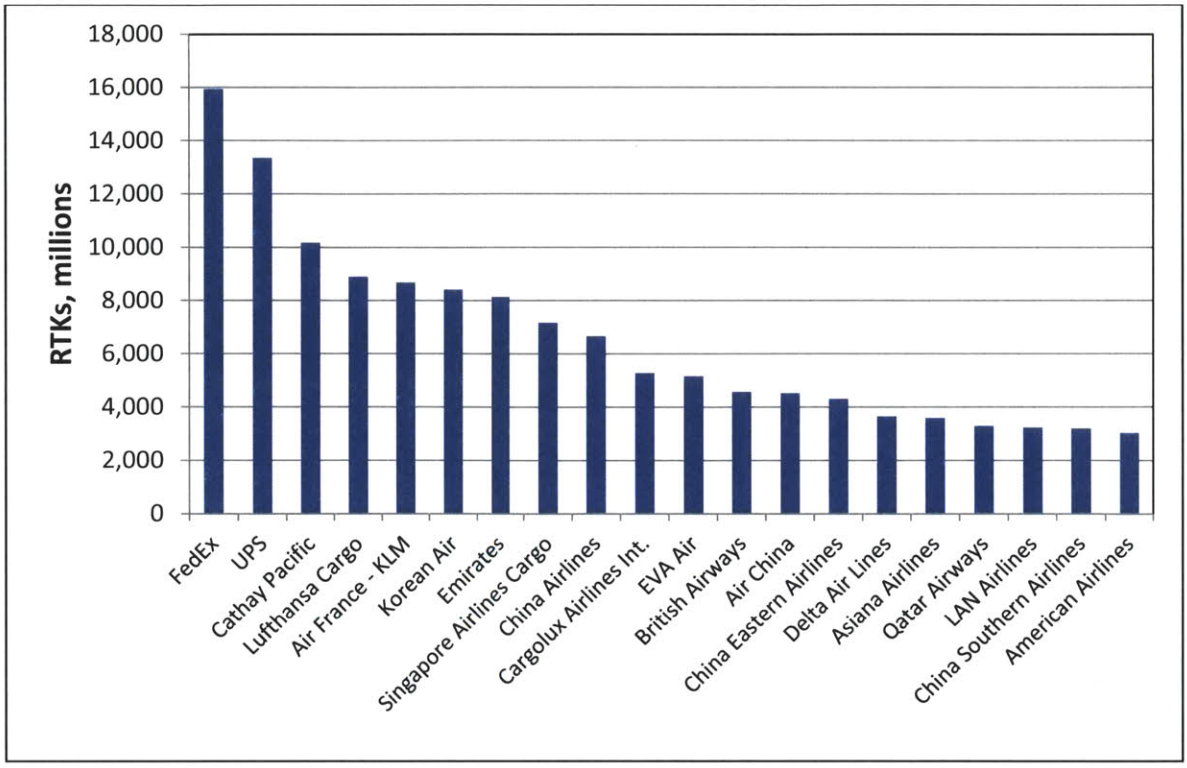

Figure 5. 2010 Top 20 World Cargo Carriers Ranked by RTK

Source: *Airline Business*

Studying the evolution of carriers through the past decade provides insight to the global trends previously described. Table 3 details the top five fastest growing and the bottom five slowest growing carriers, in terms of RTK growth since 2002. Qatar Airways led all carriers, growing 1564% since 2002, although this growth may be distorted because of Qatar Airways' very low base RTKs in 2002. In absolute terms, however, Qatar Airways rose from the 69th largest airline in 2002 to the 17th largest airline in 2010. The worst performer over the last decade was American Airlines, which experienced a 6% drop in cargo RTKs.

Table 3. Growth of Top-20 Cargo Carriers' RTKs

Top 5		% Growth since 2002
1	Qatar Airways	1564.2%
2	China Eastern Airlines	318.8%
3	Emirates	283.1%
4	China Southern Airlines	209.6%
5	Air China	138.0%
Bottom 5		**% Growth since 2002**
16	FedEx	9.0%
17	British Airways	8.6%
18	Singapore Airlines Cargo	3.8%
19	Air France - KLM	-4.1%
20	American Airlines	-6.0%

An important trend to recognize from these data is that the top performers are all from eastern regions, either the Middle East (Qatar Airways, and Emirates) or the Far East (China Eastern Airlines, China Southern Airlines, and Air China). The vigorous growth of eastern airlines supports the total industry growth during the past decade, along with the strong rebounds following recessionary periods (see Figure 3). Growing economies of emerging countries profoundly affected the global air cargo industry during the past decade.

Moreover, these regions are forecast to continue to support industry growth over the next 20 years. As quoted in Boeing's annual world cargo forecast, the world cargo industry is expected to grow at an annual rate of 5.9% (Boeing). Trade involving Asia or the Middle East in any capacity, originating from or terminating in, is expected to grow faster than the world average. The average growth in these eastern regions is forecasted to be over seven percent per year during the next 20 years. On the other hand, trade involving either North America or Europe, in any capacity, has a forecasted growth of just over five percent, nearly one percent less than the world average. Although the world cargo industry is expected to grow at a healthy rate

over the next 20 years, the growth relies heavily on the continued support of emerging countries' economic growth.

2.4.3 U.S. Trends

Many of the trends realized in the global air cargo industry are also evident in the air cargo traffic of US carriers; however, the trends seem more emphasized in magnitude and duration. The focus of this thesis primarily is to assess the evolution and productivity of US carrier air cargo operations. Data reporting problems exist immediately following deregulation of the airline industry in 1978. These problems were not resolved until 1983, therefore, US traffic figures have been analyzed during the period from 1983-2010. Detailed financial data were not available until 1990, therefore, financial analyses in this thesis are limited for the period from 1990-2010. Data are collected for approximately the top 11 US all-cargo carriers and the top seven US combination carriers, accounting for approximately 90% of the reported US air cargo traffic.

As discussed previously, there is a practical split in the air cargo industry between combination carriers and all-cargo carriers. Furthermore, it is of interest how the relationship between these two sectors has evolved over time. Figure 6 shows the share of US Carrier RTMs between combination carriers and all-cargo carriers. It is important to note that the RTM definition used in this comparison includes only freight and mail RTMs. In the mid-1980s, combination carriers carried a greater percentage of cargo than the all-cargo carriers, approximately a 60%-40% split. Over the past three decades, the percentage of RTMs carried by all-cargo has grown consistently and significantly. This shift in RTM share can partially be explained by the emergence of dominant integrated freight companies, such as FedEx and UPS,

during the late 1980s and early 1990s. Note that there was a slight decrease in all-cargo carrier share during the Gulf War, entering the 1990s, however, strong growth returned for the all-cargo carriers in 1991. Subsequently, the growth of RTM share for all-cargo carriers through the 90s was fueled by strong growth in mail RTMs carried. This resulted from USPS signing contracts with all-cargo carriers during the 1990s while decreasing service agreements with combination carriers, as discussed in Section 2.2. All-cargo RTM share growth stalled again in the late 1990s, before surging in the early 2000s. The all-cargo share growth has slowed during the past five years, with shares currently settling near 80% of RTMs handled by all-cargo carriers and 20% by combination carriers.

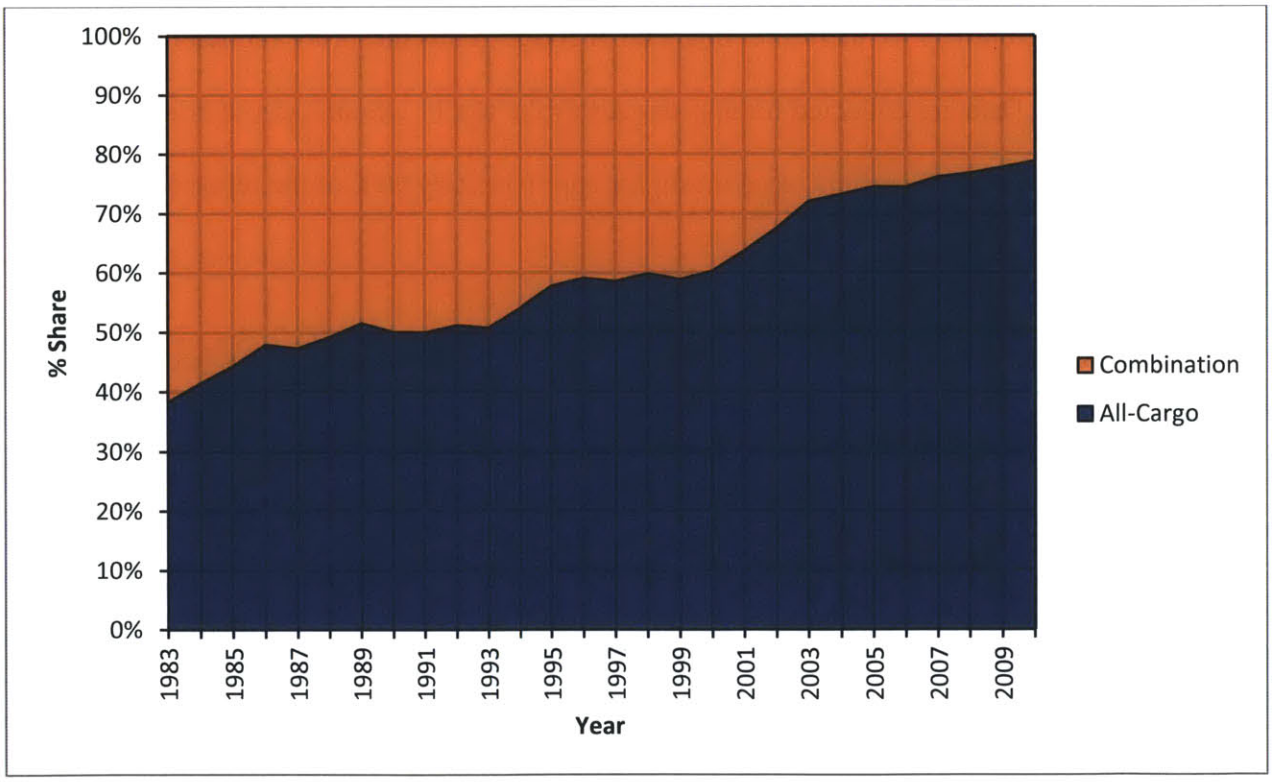

Figure 6. Share of US Carrier Cargo RTMs

All-Cargo Carrier Traffic Trends

Data from 11 all-cargo carriers represents the US all-cargo carrier trends during the past three decades. These 11 selected US all-cargo carriers account for nearly 92% of the cargo traffic carried by US all-cargo carriers from 1983 to 2010. The bar chart in Figure 7 shows the entrance and evolution of the selected all-cargo carriers. As shown, the prominent carriers included in this report are: UPS, Centurion Cargo, Emery Worldwide Airlines, FedEx, Atlas Air Inc., Polar Air Cargo, Air Transport International, Southern Air Inc., ABX Air, Evergreen International Inc., and Kalitta Air.

Data for Flying Tiger Lines are included in this section to depict the all-cargo industry trends because Flying Tiger Lines was the largest all-cargo carrier until 1989, when they were acquired by FedEx. On the other hand, data for Kitty Hawk International is not included in this analysis because of gaps and omissions in the data reported from 1984 to 1999 – in this analysis, we only include data after Kalitta Air acquired Kitty Hawk International and established operations in 2001. Challenge Air was renamed in 1999 to Centurion Cargo when UPS purchased the airline. UPS and Centurion Cargo remain operating separately, but the majority of Centurion Cargo's business provides transportation for UPS cargo. Additionally, UPS uses the name Emery Worldwide Airlines to advertise their UPS Supply Chain Solutions (UPS, 2012); however, Emery Worldwide Airlines ceased operations in 2001 as a result of poor aircraft maintenance which caused a flight crash in 2000 (CNN, 2000). Southern Air Inc. began operations in 2000 after purchasing Southern Air Transport out of bankruptcy in 1999. The entrances and exits of carriers since 1983 caused spikes in the data that affect the following analyses.

Identifying specific years when large spikes may occur will help prevent confusion when data and results are presented later in this report. Table 4 provides RTM traffic for the 11 selected US all-cargo carriers from 1990 to 2010. These data afford a sense of major changes that took place within the past two decades that affect the entire analysis. Gray shading in Table 4 indicates specific carriers and years where data outliers may exist.

Spikes in the data take place at three different times between 1990 and 2010: the early 1990s, the early 2000s, and the late 2000s. In the early 1990s, Emery Worldwide Airlines' traffic grew from 40 million RTMs in 1991 to over 900 million RTMs in 1995. Also within that time span, Polar Air Cargo entered the industry in 1993 and had traffic increase to 756 million RTMs in two years.

A lot of traffic movement occurred in the early 2000s when two carriers entered the air cargo industry, one carrier exited the air cargo industry, and another carrier grew substantially. Atlas Air began growing in 1999 and increased their traffic from 64 million RTMs to over two billion RTMs by 2002. Emery Worldwide Airlines started to record declining traffic figures in 2000 when over one billion RTMs were reported. However, in 2001, Emery Worldwide had exited the industry as a result of a flight crash in late 2000, and zero RTMs were reported by 2002. Kalitta Air entered the industry in 2001 and increased RTM traffic from 49 million RTMs in 2001 to over 1.5 billion RTMs by 2005. Similarly, ABX Air began reporting traffic in 2002 at 185 million RTMs, and, by 2003, ABX Air reported over 700 million RTMs.

The last data spike happened in the late 2000s, from 2008 to 2010. In 2009, ABX Air's reported traffic decreased by 40% from the 615 million RTMs reported in 2008 after DHL cut back US domestic service, which was one of ABX Air's largest services. However, Southern

Air and Evergreen International experienced traffic increases from 2009 to 2010. Southern Air's traffic increased 58% from around one billion RTMs in 2009 to 1.6 billion RTMs in 2010 while Evergreen's traffic increased 45% from 631 million RTMs in 2009 to 916 million RTMs in 2010.

These movements within the air cargo industry caused spikes in the data throughout the past 20 years and affect the analyses performed later in this thesis. While Table 4 provides a look at the RTMs, similar spikes occur in all of the data gathered for this thesis. Some of the spikes in other data, besides the RTMs, can be more troublesome for the ensuing productivity analyses in Chapter 4. Throughout the rest of this thesis, gray boxes on graphs indicate questionable results caused by the potential outliers described above.

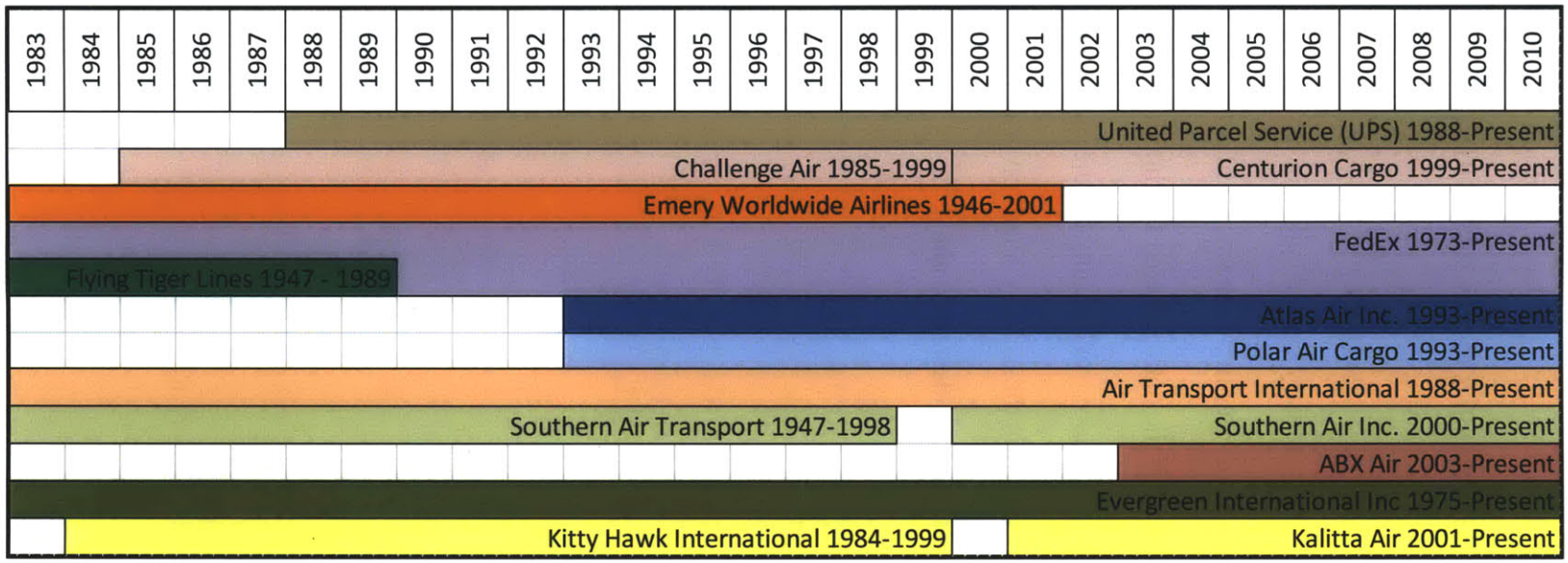

Figure 7. Selected US All-Cargo Carrier Evolution

Table 4. Selected US All-Cargo Carrier RTMs

RTMs (millions)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
5X United Parcel Service	1642	1874	2144	2492	2922	3337	3351	3472	3816	4123	4339	4431	4757	4838	5279	5762	6227	6717	6715	6311	7003
5Y Atlas Air Inc.	0	0	0	29	79	54	104	8	37	64	932	1365	2083	3319	3721	4142	3814	3745	3332	2525	3116
8C Air Transport International	128	140	146	236	317	379	429	397	298	326	289	195	202	201	224	207	259	193	162	185	224
9S Southern Air Inc.	272	236	165	223	428	578	515	152	91	0	74	127	269	106	499	695	784	1024	1400	1019	1610
ABX ABX Air, Inc.	0	0	0	0	0	0	0	0	0	0	0	0	185	701	714	619	571	646	615	361	467
EZ Evergreen International Inc.	212	312	230	332	370	406	451	668	872	794	792	442	389	679	737	829	841	753	611	631	916
FX Federal Express Corporation	4461	4199	4285	4234	4791	5120	5635	6425	6843	7094	7837	7609	9094	9488	9991	10028	10544	10965	10591	9686	10921
KAQ/CDQ Kalitta Air LLC/ Kitty Hawk	0	0	0	0	0	0	0	0	0	0	0	49	247	660	1171	1562	1190	1358	1175	944	1140
PO Polar Air Cargo Airways	0	0	0	0	181	756	940	1315	1004	961	1136	950	1349	1645	2336	1780	1571	1268	1178	1182	1409
TNQ Emery Worldwide Airlines	7	40	596	640	848	935	965	971	1041	1161	1048	719	0	0	0	0	0	0	0	0	0
WE Centurion Cargo Inc.	121	134	162	147	156	173	183	207	225	211	154	18	16	118	202	470	189	251	232	181	210

FedEx and UPS have been separated from the other nine all-cargo carriers for analysis in this thesis because of distinct differences in operations. As described in sections 2.2 and 2.3, FedEx and UPS operate vertically integrated business models that require strict service schedules and consolidated cargo services, whereas the other all-cargo carriers tend to operate based on chartered services. In other words, FedEx and UPS transport their own cargo according to their own service schedule while the other all-cargo carriers wait to accept cargo from a customer. This does not mean that the other all-cargo carriers operate without a schedule, but rather that their customers influence the schedule and operations. The differences between FedEx/UPS' operations and the other all-cargo carriers' operations affect traffic figures, which are explored below. Additionally, FedEx and UPS combined for between 60%-91% of the total US all-cargo RTMs carried between 1983 and 2010. Separating FedEx and UPS allows for a more transparent analysis of the other nine all-cargo carriers.

Traffic figures for FedEx and UPS since 1983 are displayed in Figure 8. Both RTMs and ATMs increased up during the latter half of the 1980s. However, RTMs grew more slowly than ATMs, and, as a result, load factor realized a general decreasing trend with the exception of 1987, when load factor increased to 66%. It is important to note and understand why air cargo load factors appear much smaller than the average passenger load factors nearing 80% in 2007 (Belobaba, 7). As described in Section 2.2 Integrator Evolution, FedEx and UPS operate low utilization services with an emphasis on moving cargo quickly. This often results in airplanes departing with a less-than-full load and, therefore, a lower load factor. Traffic growth slowed entering the 1990s because of the oil price shock and subsequent mini-recession, with ATMs hovering around 11 billion ton-miles and RTMs near 6 billion ton-miles. During this time, load factor dropped to 56% before the 1990s, a decade of substantial growth.

RTMs grew at an average rate of approximately 10% per year during the 1990s, while ATMs grew at an average rate of approximately 8.5% per year over the same time. By 1999, the ATMs in the system almost doubled, from 10.5 billion ton-miles to nearly 20 billion ton-miles. Similarly, RTMs increased from about six billion ton-miles to a little more than 12 billion ton-miles. Additionally, load factor rebounded strongly after the 1990 recession, jumping from 56% in 1991 to 60% in 1994. The prosperous growth experienced throughout the 1990s slowed starting in 1998, when ATMs grew only 6.8% from 1998 to 2000. RTMs, however, grew over 14% during this period, causing a four percent increase in load factor to just over 62%.

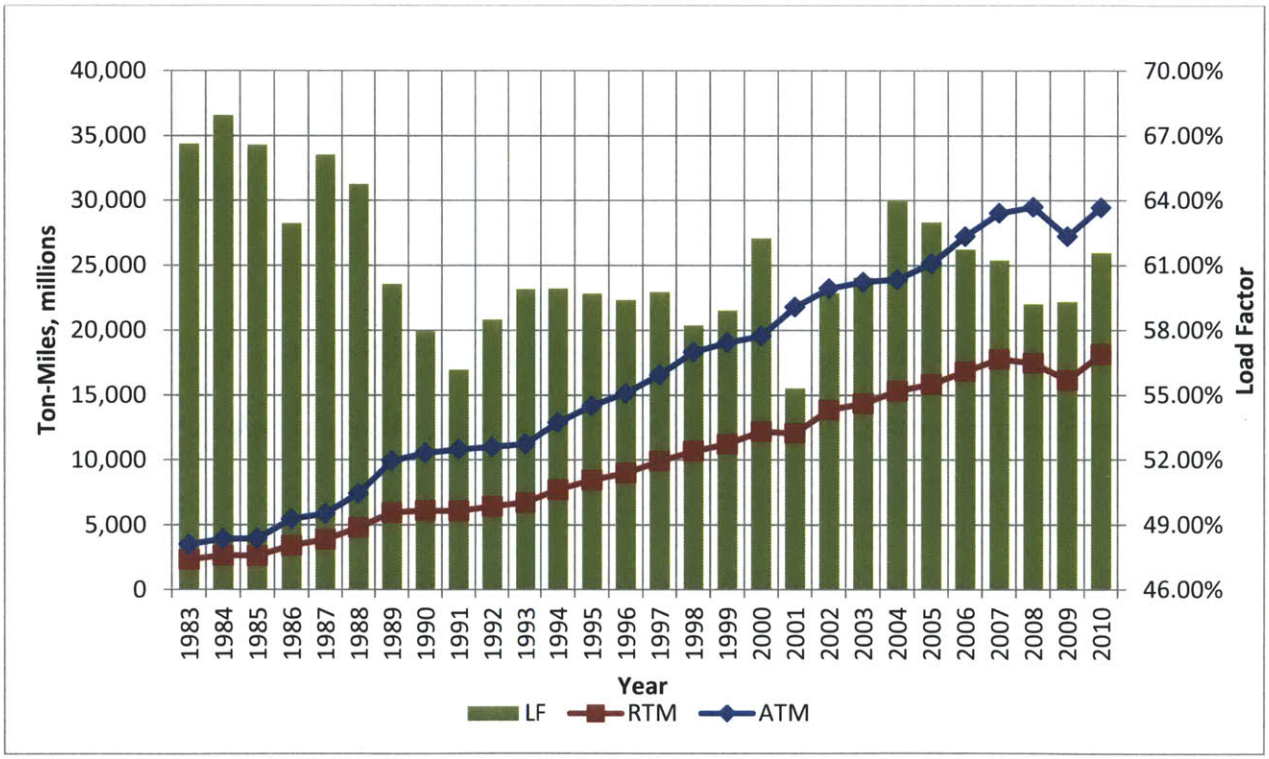

Figure 8. FedEx and UPS Traffic and Capacity

In 2001, RTMs dropped approximately one percent in response to the declining economy of the US and to the terror attacks of September 11. At the same time, however, ATMs grew over 11%, causing more than a seven percent drop in load factor in 2001, from 62% to 55%.

RTMs recovered strongly, exceeding pre-2001 levels the very next year, growing 28% over the next five years. ATM growth slowed in the early 2000s, and, subsequently, load factor rebounded, peaking at 64% in 2004.

Over the next four years, 2004-2008, ATMs grew nearly six percent per year, while RTM growth remained steady at around five percent per year. Load factor declined from 2004 to 2008 as ATMs grew faster than RTMs. When the economic recession occurred in the US in 2008-2009, ATMs decreased 7.5% to 27.2 billion ton-miles and RTMs decreased eight percent to 16.1 billion ton-miles. However, similar to the recession occurring from 1990-1991, traffic figures rebounded in 2010, with ATMs reaching pre-2008 levels and RTMs reaching all-time highs, more than 18 billion ton-miles. This positive growth is further realized in a 2.5% load factor growth from 2009 to 2010, hinting at a strong recovery for FedEx and UPS coming out of the recession.

Traffic figures for the other nine all-cargo carriers are provided in Figure 9. Both ATMs and RTMs increased more than 300% from 1983 to 1989 for the other all-cargo carriers. However, in 1985, RTMs remained approximately constant while ATM growth continued, causing an 11% drop in load factor, from 55% to 44%. RTMs growth restarted the next year, and, by 1989, load factor grew back to 55%. When the mini-recession occurred in 1990, capacity was removed by the all-cargo carriers, realized as a 21% drop in ATMs. However, RTMs only decreased 17%, which caused load factor to increase 2% that year. This increase in load factor marked the beginning of a prosperous period of traffic growth from 1990 to 1997.

By 1997, ATMs and RTMs were at 5.7 billion ton-miles and 3.7 billion ton-miles, respectively, representing 345% growth in ATMs and 400% growth in RTMs since 1990. Load

factor increased from 57% in 1990 to nearly 66% in 1997, as a result of RTMs growing faster than ATMs during the 1990s. In the late 1990s, growth stalled, and ATMs steadied near six billion ton-miles and RTMs leveled off near four billion ton-miles.

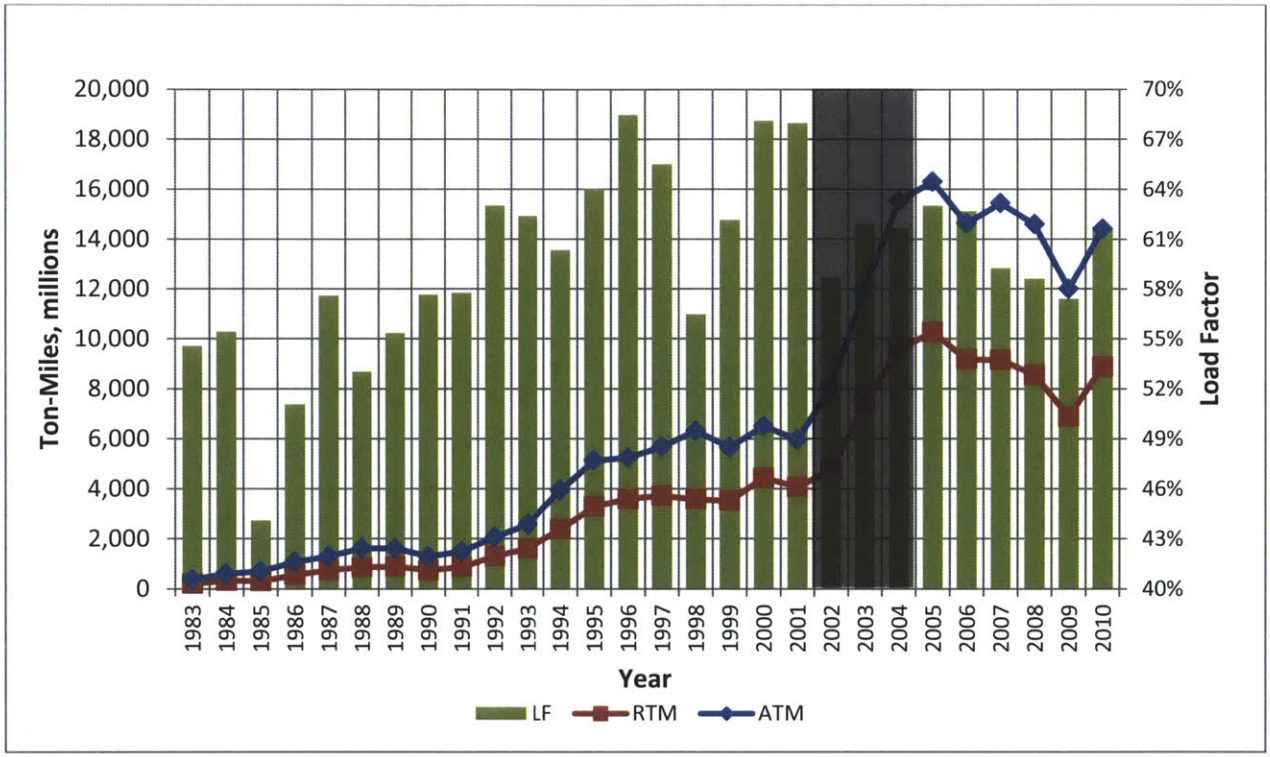

Figure 9. Other US All-Cargo Carrier Traffic and Capacity

The stalled traffic growth remained through 2001 during the declining US economy and the September 11 terror attacks. However, RTMs grew in 2000 while ATM growth lagged, resulting in an 11.5% load factor growth from 1998 to 2001. Growth picked up in 2002, and traffic more than doubled over the next four years. ATMs grew 172% from six billion ton-miles in 2001 to 16.3 billion ton-miles in 2005, and RTMs grew from four billion ton-miles in 2001 to 10.3 billion ton-miles in 2005, a 157% increase. Load factor dropped five percent during this same time period, however, because capacity (ATMs) grew faster than traffic (RTMs). Recall

from previous discussions that data during this period may be obscured by the entrance and growth of cargo carriers. A gray box in Figure 9 indicates the specific data range that may be questionable. The substantial growth of Atlas Air in the early 2000s, along with the entrances of ABX Air and Kalitta Air, bolstered traffic growth from 2002 to 2004. While most carriers' traffic grew during the early 2000s, it is questionable that the growth of three specific carriers could result in over 150% growth of the industry in three years.

ATM capacity remained around 15 billion ton-miles from 2006 to 2008, but RTM traffic began decreasing, dropping from 9.2 billion ton-miles in 2006 to just over 8.5 billion ton-miles in 2008. Decreasing RTMs resulted in a declining load factor leading into the 2008-2009 economic recession. In 2009, RTMs bottomed out at 6.9 billion ton-miles, approximately 33% below the peak levels of 2005. ATMs dropped 26% from 2005 to 2009, bottoming out at 12 billion ton-miles. Removing some excess capacity from the system, shown as decreasing ATMs, slowed load factor decline, with load factor eventually bottoming out just below 58% in 2009. Similar to the previous recession periods, 1990-1991 and 2001, traffic figures appear to be recovering strongly out of the recent recession. RTMs have grown and surpassed 2008 levels, while ATMs have not grown quite as fast, showing promising growth in load factor that could facilitate increasing yields and revenues in the near future.

Strong traffic recovery was recognized following the two recent recessions in 2001 and 2008-2009, as discussed above. Specifically, recovery was fueled by cutting capacity at a quicker rate than RTMs decreased. The trends discussed above are reaffirmed by the evolution of the US cargo fleet, seen in Figure 10. Note that this graph includes the dedicated cargo jets operated by combination carriers. Capacity decreased approximately 12% from 2001 to 2003, supporting the recovery out of 2001. Subsequently, the fleet experienced a significant drop in

2009-2010, decreasing nearly 20%. This drop resulted from two factors. First, recall that DHL removed their US domestic service at the end of 2008. This action specifically hurt ABX Air, reducing their fleet capacity. Additionally, large combination carriers, such as Northwest Airlines and American Airlines, began grounding their dedicated cargo fleet in the late 2000s in favor of accepting less overall cargo by utilizing belly hold capacity on passenger aircraft. This topic is discussed in more detail throughout the analysis of combination carriers below. Overall, restraining capacity in the early 2000s and 2010 fostered the traffic recoveries realized during those years.

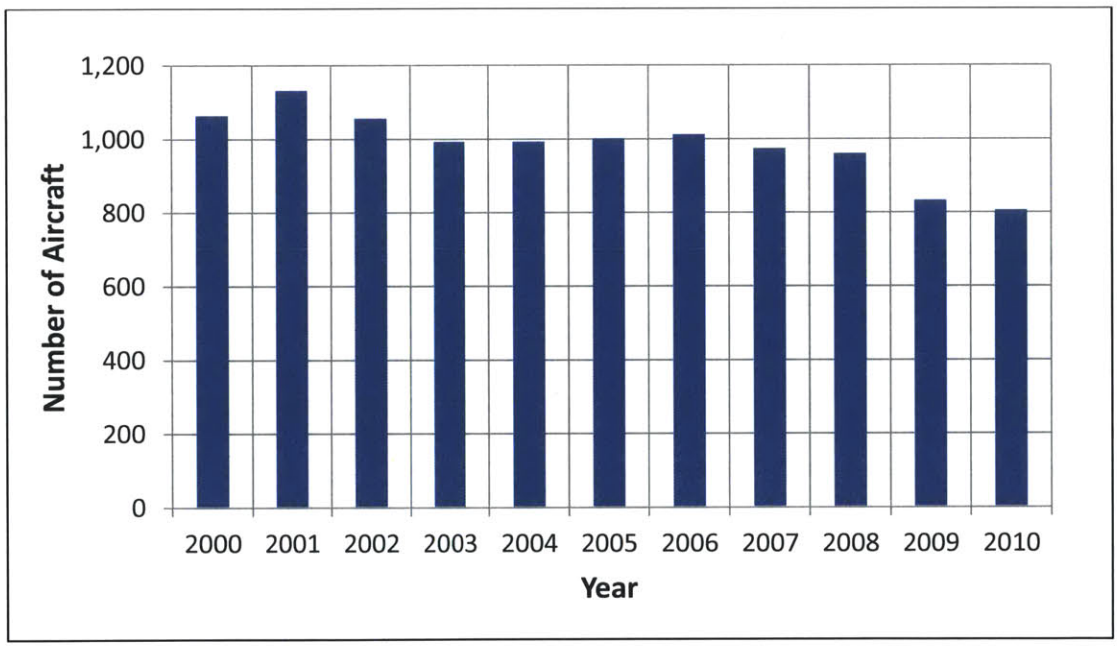

Figure 10. US Cargo Jet Fleet Size

Source: BTS Form 41

All-Cargo Carrier Operating Cost Trends

Deregulation of the US airline industry generated competition, forcing airlines to remain competitive on prices while helping to control and drive down operating costs. This section explores operating costs, separating the total operating expense into four categories: fuel, labor,

ownership, and intermediate. Unit costs, operating expense per ATM, are explored using the same four categories mentioned above. Since 1990, operating expenses have increased in terms of 2010 dollars. However, competition has driven down unit costs over the past 20 years, even while fuel prices have hiked to all-time highs.

Operating expense (OPEX) is divided into four common categories for US airlines in this thesis – fuel, labor, ownership, and intermediate. Fuel expenses are straightforward and include the total cost of fuel required to operate an airline's fleet. In the past decade, extreme volatility characterized fuel prices, causing extreme increases in airlines' fuel expenses; airlines now implement fuel price hedging to control fuel expenses. Labor costs include total salaries, benefits, and other costs paid by airlines to employees. Ownership costs consist of depreciation and amortization costs associated with aircraft ownership, and aircraft rental costs – these represent the capital tied up in owning aircraft used for operations. The intermediate expense category represents all other costs incurred by the airline, such as maintenance, advertising, insurance, airport fees, etc. It is important to note that transport related[1] and passenger related expenses have been excluded from this analysis because these costs do not contribute to all-cargo operations. Over the past 20 years, transport related costs have accounted for 20% -30% of total OPEX for all-cargo carriers, while passenger related expenses have accounted for less than 1% of total OPEX. For the remainder of this thesis, OPEX will refer to expenses excluding transport related and passenger related expenses.

Figure 11 shows the evolution of total OPEX for FedEx and UPS from 1990 to 2010 in terms of 2010 dollars. Total OPEX grew 195% from 1990 to the peak in 2008, rising from $6.5

[1] As reported in BTS Form 41, transport related expenses are defined as payments made by one airline for services provided by a second airline, such as short-haul transport of cargo

billion to $19.2 billion. Expenses dropped to approximately $15 billion during the economic recession in 2009, before increasing to $17 billion in 2010 as the economy began to recover. Rising fuel expenses influenced total OPEX growth the most over the past 20 years, growing $4.74 billion from 1990 to the peak in 2008. Additionally, intermediate costs increased by approximately $4.2 billion, labor costs increased by nearly $3.0 billion dollars, and ownership costs increased by $800 million over the same time span.

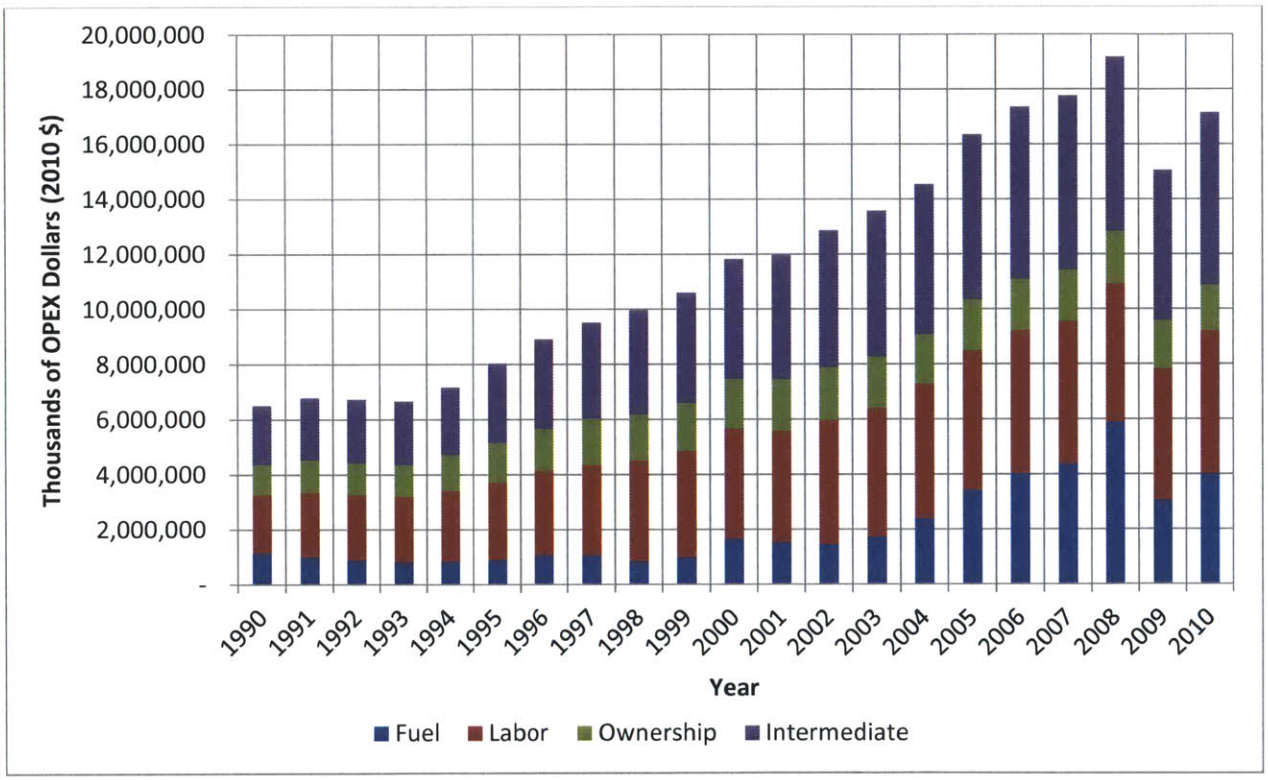

Figure 11. FedEx and UPS Operating Expense

Even though real operating costs have increased, analyzing unit costs reveals a somewhat different trend. Figure 12 displays the evolution of unit costs, OPEX per ATM, for FedEx and UPS from 1990 to 2010. The operating expenses used to calculate unit costs were first inflated

to 2010 dollars. As shown, unit costs have remained near 60 cents per ATM for the past 20 years, decreasing only four cents per ATM over 20 years, from 62 to 58 cents per ATM.

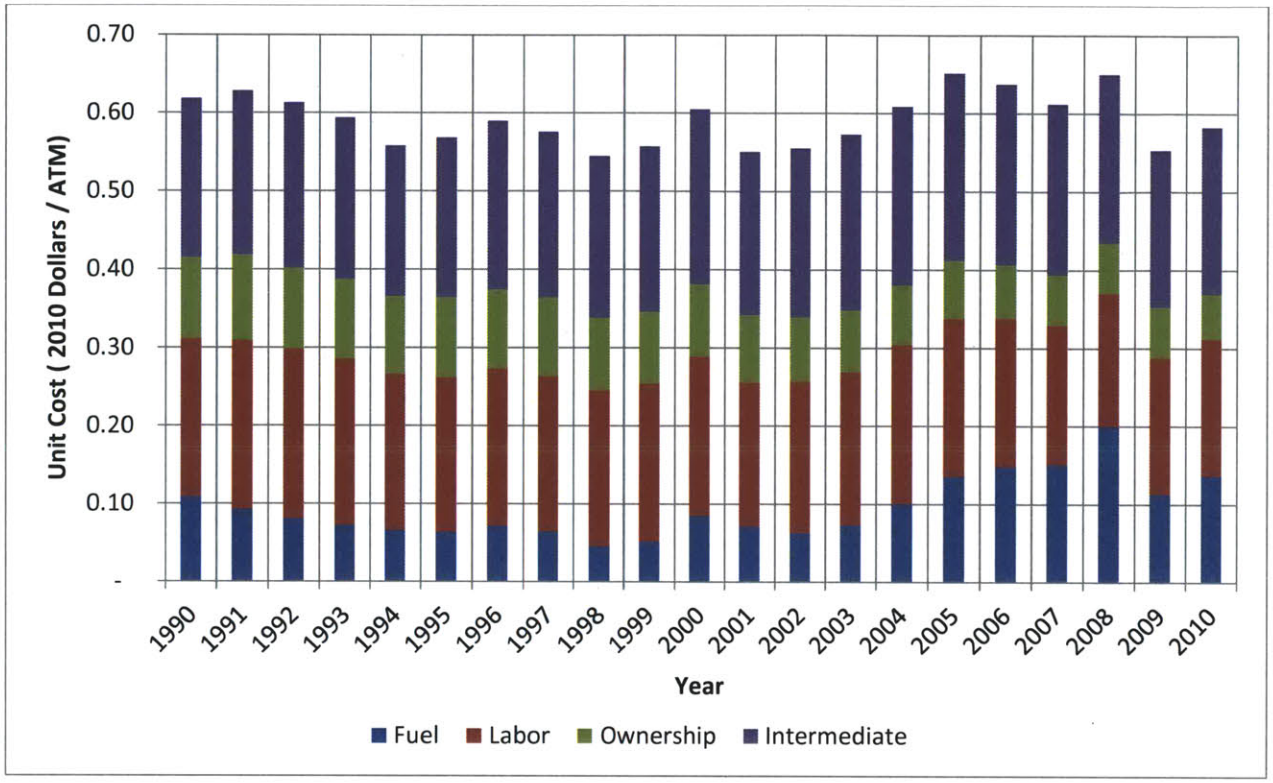

Figure 12. FedEx and UPS Unit Costs

Although total unit costs did not change much for FedEx and UPS over the past 20 years, significant changes were realized in the relative shares of unit costs. Fuel expense as a percentage of total OPEX increased the most from 17% in 1990 to 23% of total OPEX in 2010; most of this increase occurred in the mid-2000s as the price of fuel reached all-time highs. During the same time span, intermediate expenses grew four percent, while labor expenses and ownership costs have decreased three percent and seven percent, respectively.

Operating expenses for the other nine all-cargo carriers grew similarly to FedEx's and UPS' operating expenses. Figure 13 shows the evolution of operating expense for the other all-cargo carriers in 2010 dollars. Total OPEX grew from approximately $600 million in 1990 to a

peak of $4.75 billion in 2008, before decreasing back to $3.75 billion in 2010 following the economic recession through 2009. Rising fuel prices in the mid-2000s increased fuel expenses by $1.41 billion from $390 million in 2000 to over $1.8 billion in 2008, and caused most of the increase realized in total OPEX during the past 20 years. Ownership, labor, and intermediate costs grew in real terms, but nowhere near the magnitude that fuel costs had increased. Since 1990, ownership costs increased $488 million, labor costs grew $615 million, and intermediate costs increased $840 million.

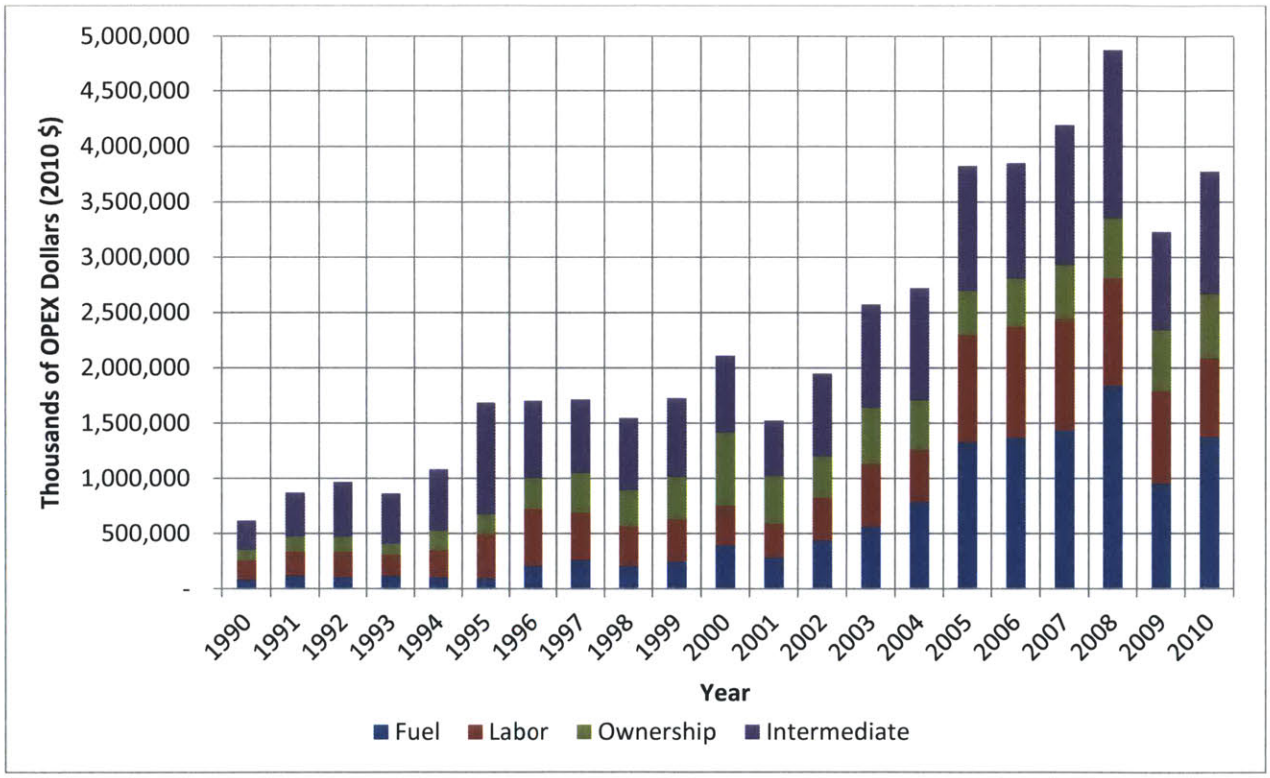

Figure 13. Other All-Cargo Carrier Operating Expense

Although operating expense trends for the other all-cargo carriers mirrored trends for FedEx's and UPS' operating expenses, unit cost trends differed. Figure 14 provides the trend of unit costs, in 2010 dollars, from 1990 to 2010. Unit costs for the other all-cargo carriers neared

50 cents per ATM in the early 1990s, but decreased almost 40% to 32 cents per ATM in 2000. This reduction in unit costs was caused primarily by introducing new capacity into the system; larger planes with larger cargo holds and longer flights (stage lengths) spread fixed costs over increased capacity and drive down unit costs. Decreases in unit costs continued into the 2000s as capacity continued to enter the industry. Unit costs reached a low of 18 cents per ATM in 2004, before rising fuel prices and capacity cuts increased unit costs to 33 cents per ATM in 2008.

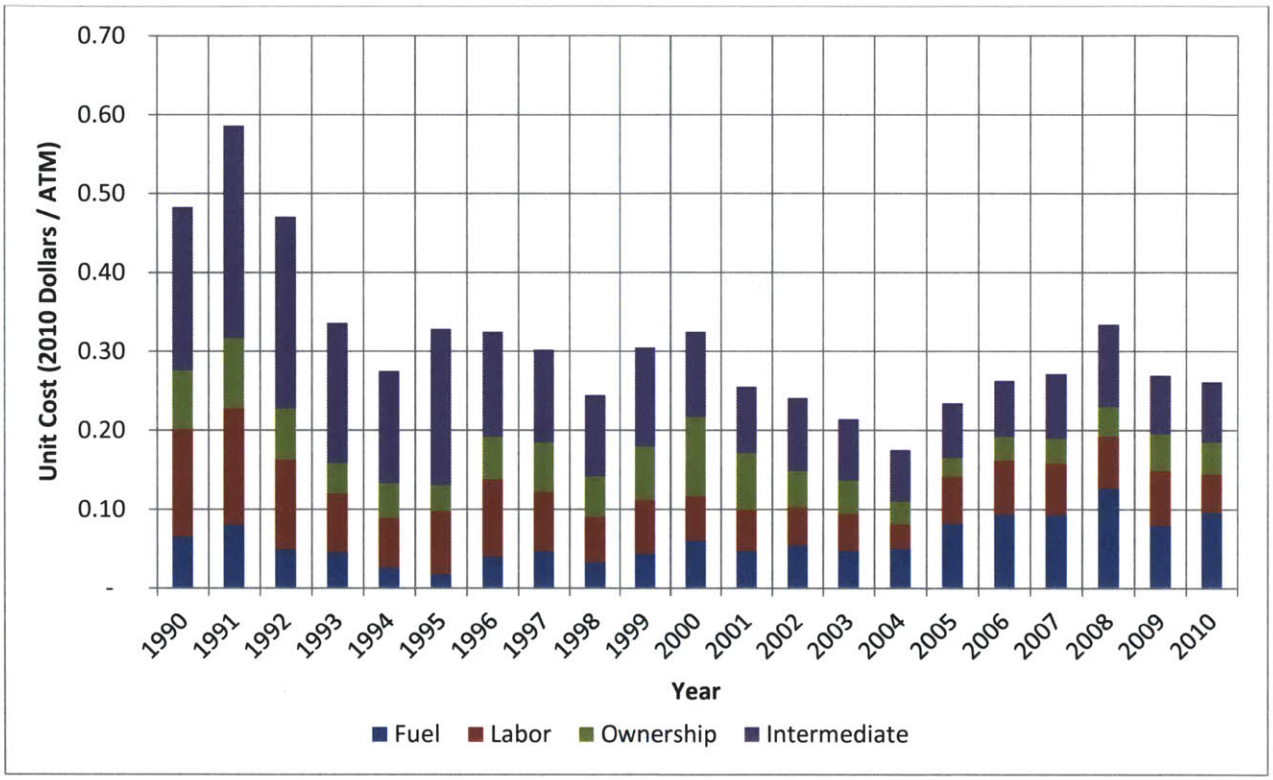

Figure 14. Other All-Cargo Carrier Unit Costs

It is clear from this analysis that fuel expense played a major role in other all-cargo carrier costs during the past 20 years, especially the past decade. In 1990, fuel expense represented approximately 14% of total OPEX, whereas fuel expense constituted 36% of total OPEX in 2010. On the other hand, from 1990 to 2010, the share of intermediate costs decreased

from 43% to 29%, and the share of labor costs decreased from 28% to 19%. Ownership cost share remained about the same as a percentage of total OPEX from 1990 to 2010.

Combination Carrier Traffic Trends

Data were gathered from seven US network legacy carriers (NLCs) to represent the US combination carrier cargo industry. The seven carriers include: American Airlines, Alaska Airlines, Continental Air Lines, Delta Air Lines, Hawaiian Airlines, Northwest Airlines, and United Air Lines. Additionally Pan American World Airways data are included until 1991, when the airline declared bankruptcy and was acquired by Delta Air Lines. These carriers were selected based on a combination two factors: cargo revenues exceeded two percent of total operating revenues, and cargo RTMs constituted over 10% of total RTMs (cargo plus passenger). Not all carriers satisfied these two criteria each year, but, over the period of analysis, these seven selected carriers showed serious involvement in cargo operations through the combination of the two criteria. These seven US NLCs account for approximately 90% of the total cargo traffic carried on US combination carriers from 1983-2010.

Cargo traffic figures for US combination carriers since 1983 are displayed in Figure 15. The RTM and ATM data presented have been adjusted to remove a standardized weight per passenger that airlines include in data reported to the BTS (approximately 0.1 tons/passenger)[2]. Cargo traffic carried by combination carriers experienced significant growth from 1983 to 1990, with ATMs doubling and RTMs growing approximately 70% during that time span. As a result of ATMs growing faster than RTMs, load factor decreased from about 39% to 32% in 1990.

[2] A method is explained in section 3.1-Data Availability for calculating cargo-only statistics for combination carriers

RTM and ATM growth continued through the 1990s, however not as strong as the rapid growth experienced through the late 1980s. ATMs continued to grow faster than seven percent per year through the 1990s, while RTM growth slowed to just greater than five percent per year. This resulted in load factor dropping slightly greater than two percent during the 1990s.

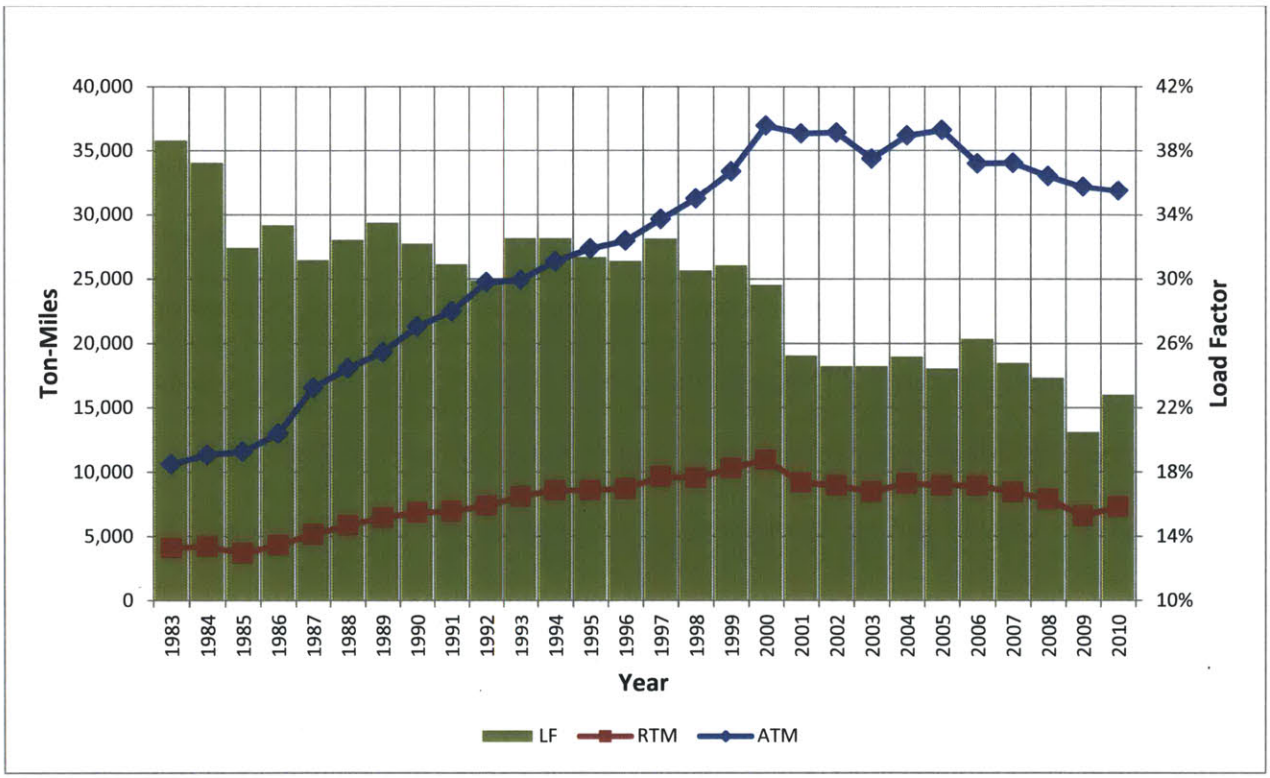

Figure 15. US Combination Carrier Cargo Traffic

The economic recession entering the 2000s, followed by the September 11 terror attacks, caused a decline in RTM and ATM, and subsequently a sharp drop in load factor of nearly five percent. RTMs and ATMs continued to decline through the rest of the decade, with RTMs decreasing faster than ATMs, as realized in a steadily decreasing load factor. Load factor reach an all-time low of approximately 20% in 2009, during the economic recession when RTMs

reached a twenty-year low. A sign of recovery occurred in 2010 when RTMs increased 10% while ATMs remained approximately constant, causing a 2.5% increase in load factor.

Increased security measures may be one explanation for the consistent decrease in RTMs and load factor during the 2000s. After the attacks on September 11, the US Department of Homeland Security mandated that all cargo carried on passenger airlines must be security screened prior to the flight, as part of the 9/11 Act of 2007 (Morrell, 170). Implementing this security screening imposed major costs for combination carriers for such a small portion of their total traffic – recall that cargo only accounts for about 3% of total revenues for combination carriers. As a result, combination carriers began limiting their cargo operations in the late 2000s, with large NLCs such as Northwest Airlines grounding their all-cargo jets in favor of accepting less overall cargo by utilizing the belly holds of passenger aircraft.

Combination Carrier Cargo Operating Cost Trends

This section explores the operating costs of US combination carriers since 1990. As with all-cargo carriers, deregulation drove competition amongst combination carriers and forced airlines to control operating expenses. Total OPEX presented in this section is split into four categories: fuel, labor, ownership, and intermediate. These four categories represent specific airline costs as described previously in the all-cargo section. However, the expenses reported in this section for combination carriers represent only the cargo-related expenses for each category. Cargo-related expenses were determined using the proportional profit-cost allocation method described in Section 3.1.2 Financial Data. This section also presents unit costs since 1990, where unit costs represent the cargo-related operating expenses per cargo ATM.

Combination carriers have experienced declining operating expenses, in 2010 dollars, for most of the past two decades. Figure 16 provides the trend of total cargo OPEX for US combination carriers from 1990 to 2010. Total OPEX grew in the early 1990s and peaked at approximately $3.4 billion in 1993, driven primarily by a 30% growth in labor costs during the same time period. However, OPEX dropped quickly over the next three years as intermediate expenses fell 35%. From 1996 to 2007, combination carrier operating cost hovered around $2.5 billion. In the early 2000s, labor expenses decreased when US NLCs began restructuring labor contracts after declaring bankruptcy. However, total operating expenses remained constant as a result of increasing fuel prices from 2003 to 2008; fuel expenses grew 200% during this time while labor expenses decreased 35%. Fuel expenses peaked in 2008, causing a spike in total OPEX. Though, total OPEX dropped almost $1.0 billion dollars from 2008 to 2009 during the US economic recession. Over the past 20 years, total OPEX decreased 35% from $2.74 billion in 1990 to $1.77 billion in 2010.

US combination carriers have achieved significant cargo-related cost reductions over the past two decades as a result of improved cost efficiencies such as renegotiated labor contracts and reduced intermediate costs. However, it is important to recall that the costs presented here are calculated using the profit-cost allocation method. As discussed in the previous section, combination carriers have limited their cargo operations during the past decade, and cargo revenues as a percent of total revenues have decreased from approximately 3.6% in 2000 to 2.7% in 2010. Therefore, some of the cost reductions realized in Figure 16 resulted from combination carriers decreasing their cargo operations, rather than improved cost efficiencies.

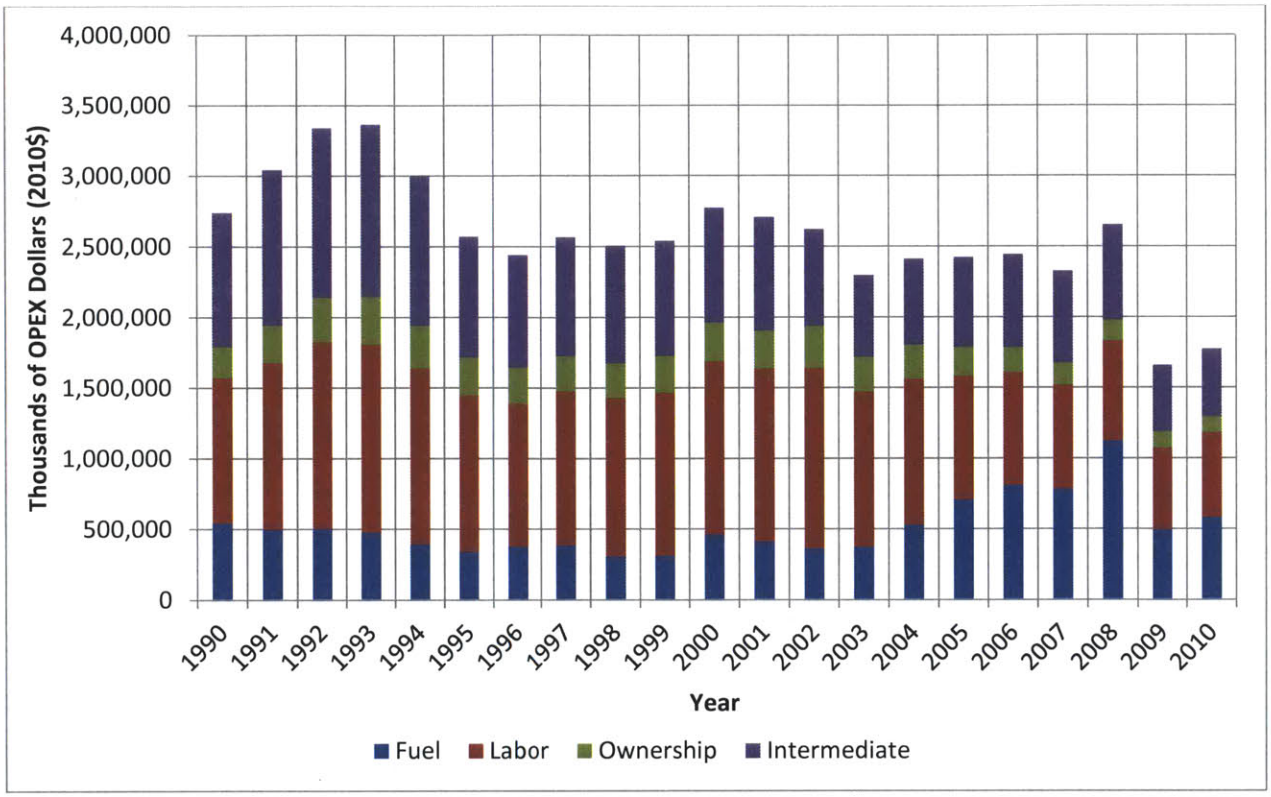

Figure 16. Combination Carrier Cargo-Related Operating Costs

Similar to total cargo-related OPEX, cargo-related unit costs have decreased over the past 20 years. Figure 17 shows the trend of US combination carriers' cargo-related unit costs from 1990 to 2010 separated into the four OPEX categories. Unit costs have decreased 60% in the past 20 years from 14 cents per cargo ATM in 1990 to 5.6 cents per cargo ATM in 2010. As discussed previously, labor expense cuts and decreasing intermediate costs fueled this unit cost reduction; labor unit costs have decreased 64% since 1990 from 5.4 cents per cargo ATM to 1.9 cents per cargo ATM, and intermediate unit costs decreased from 4.9 cents per cargo ATM to 1.5 cents per cargo ATM, a 69% reduction. Ownership unit costs decreased 73% over the past two decades, but these costs make up only about 7% of total OPEX and, thus, have not had a profound effect on decreasing unit costs. Fuel unit costs decreased until the mid-2000s when

fuel expenses soared, as discussed above. In 2008, fuel unit costs peaked at 3.4 cents per cargo ATM, but dropped to 1.8 cents per cargo ATM in 2010 as total unit cost decreased.

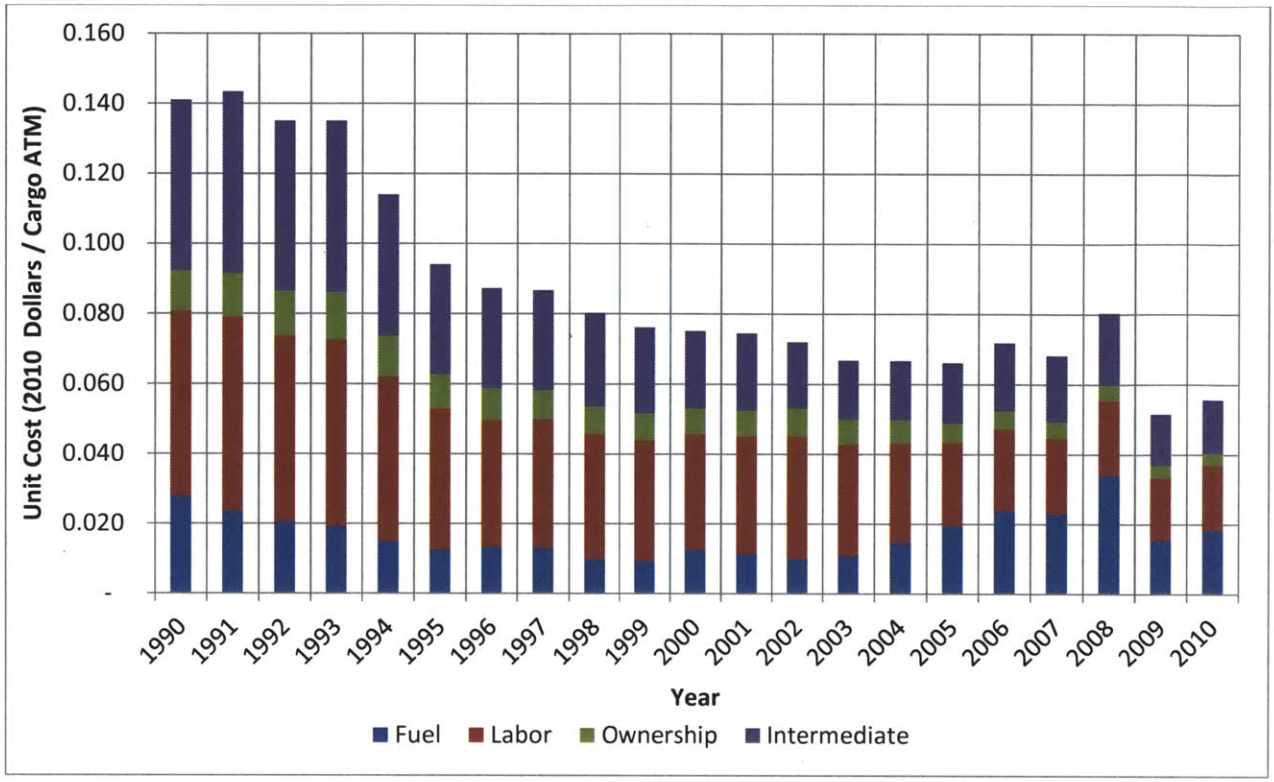

Figure 17. Combination Carrier Cargo-Related Unit Costs

Increasing fuel costs while decreasing labor, ownership, and intermediate costs has shifted the relative weight of each of expense category as a percentage of total OPEX. In 2010, fuel expense as a percentage of total OPEX represented 33% of total OPEX, whereas fuel expense was 20% of total OPEX in 1990. The other three expense categories have decreased as a percentage of total OPEX from 1990 to 2010. Labor expenses decreased from 37% to 34%, intermediate expenses decreased from 35% to 27%, and ownership expenses decreased from eight percent to six percent.

Again, it is worth noting that some of the decrease noticed in unit costs resulted from combination carriers limiting cargo operations. Therefore, the revenues gained through carrying cargo have decreased, meaning that the proportional profit-cost allocation method for calculating cargo OPEX, as described in section 3.1.2, correspondingly decreases cargo expenses. Ultimately, while combination carriers have improved cost efficiencies, especially through renegotiating labor contracts and reducing intermediate and ownership costs, part of the cargo OPEX cost reduction over the past 20 years results from an overall decrease in cargo operations.

2.5 CHAPTER SUMMARY

In this chapter, we explored the historical evolution of the US air cargo industry from the early 1900s to deregulation of the airline industry in 1978. This historical discussion provided context to discuss the emergence of integrated freight carriers, FedEx and UPS, in the mid-1900s. FedEx's and UPS' business are described along with the key characteristics that define them as integrated freight companies. A more general discussion about air cargo operations for combination carriers and all-cargo carriers follows the FedEx and UPS discussions. The last section of this chapter presented recent air cargo trends, beginning with an overview of the global air cargo industry in the past decade. An in-depth analysis of the US air cargo industry showed that the all-cargo industry has grown significantly in the past 30 years, in terms of ATMs and RTMs, but that combination carrier cargo traffic, specifically RTMs, have decreased within the past decade as NLCs opt to limit cargo operations because of imposing security regulations instated following the September 11th terrorist attacks. Analyses of operating expenses show that FedEx's and UPS' unit costs remained approximately constant over the past 20 years while other all-cargo carriers and combination carriers have decreased unit costs significantly.

The following chapter explains the available data for this thesis and presents methodology that is at the crux of the productivity analyses presented in Chapter 4. Traffic analyses and operating expense analyses shown in this chapter provide context of the US air cargo industry over the past 20 years, helping to understand and to explain fully the productivity results presented in Chapter 4.

3. PRODUCTIVITY METHODOLOGY

This chapter discusses the available data for this thesis and explains the productivity metrics that were generated to assess the US air cargo industry. Single-factor productivity metrics are presented to measure the ability of US air carriers to convert various inputs, such as operating expenses, fuel, capital, and labor, into cargo outputs, revenue-ton-miles (RTMs) and available-ton-miles (ATMs). Additionally, this chapter describes a multi-factor productivity metric that compares a given output to a combination of inputs.

3.1 DATA AVAILABILITY

Data used in this thesis to evaluate productivity of US air cargo carriers were gathered from the US Bureau of Transportation Statistics (BTS). The BTS collects a variety of data from US air carriers, including air traffic figures, financial data, fuel consumption and fuel cost data, and labor statistics. Traffic figures are reported reliably from the early 1980s, but the detailed financial, fuel, and labor data date back only to 1990. Therefore, this thesis limits productivity analyses to the past two decades, from 1990 to 2010. Some modifications to the data are required to compare the combination carriers' productivity on a fair basis, as we shall explain in the following subsections. Additionally, data availability from the BTS and the application of data modifications are described in the following subsections.

3.1.1 Traffic Data

The traffic data consists of available-ton-miles (ATMs), revenue-ton-miles (RTMs), block hours, and aircraft-days. Block hours are defined as the time that an aircraft spends from leaving the departure gate until the aircraft enters the arrival gate, including any delays while the

aircraft sits on the runway, and aircraft-days represent a measure of fleet size over a year. Reported ATMs include passenger weight for combination carriers; a method is described below to subtract the passenger weight and determine the available-ton-miles apportioned for cargo on combination carriers. RTMs are reported in the following subcategories: freight, mail, and passengers.

Freight and mail RTMs can be used for all-cargo and combination carriers as reported because these data represent the actual traffic moved by the carrier. Similarly, ATMs are used as reported for all-cargo carriers because the entire available payload on a freight aircraft is dedicated to carrying cargo. However, this is not the case for combination carriers. A modification is required to subtract the passenger weight from the reported ATMs and create an ATM_{cargo} statistic for combination carriers. When airlines report ATM data to the BTS, they account for passengers and baggage using a representative weight (pounds or kg per passenger) for available seats. This weight typically is in the range of 180-200 lbs/passenger, or 80-90 kg/passenger (Morrell, 231). For this thesis, a high-end range estimate is used, 200 lbs/passenger. Equation 1 below calculates ATM_{cargo} by subtracting this standard unit weight multiplied by system available-seat-miles (ASM) from the total reported ATMs.

$$ATM_{cargo} = ATM_{total} - 200lbs * ASM \qquad \text{(Eq. 1)}$$

Multiplying the ASMs by the passenger load factor, where load factor is defined as the system revenue-passenger-miles (RPMs) divided by the system ASMs, for a given year was explored, but was rejected for several reasons. First, studies of passenger traffic evolution over the past two decades reveal that passenger load factor has increased significantly, from approximately 60% in 1986 to around 80% in 2007 (Belobaba, 7). If passenger load factor would be included in the above calculation, the increase in passenger load factor automatically

would deflate any cargo productivity metric by introducing exogenous factors such as passenger revenue management systems. Although, one may note that if a greater number of passengers are carried on a given plane, there is less available payload for cargo. However, the amount of cargo carried on an airplane is also limited by the belly hold volume, not just the available payload. In other words, even though a passenger may not be sitting in a seat, freeing available payload for cargo, the available volume allotted for cargo has remained unchanged because freight cannot replace a passenger in a given seat. Lastly, excluding load factor from the calculation allows for a basic modification to ATMs and provides a conservative ATM_{cargo} estimate that can be applied consistently across all combination carriers over time; LF variances for different carriers over time will not affect the calculation.

Block hours and aircraft-days are used to calculate the system average aircraft utilization by dividing the reported block hours by the aircraft-days. Aircraft utilization provides some insight into the operational differences between individual carriers, or even between all-cargo and combination carriers. As described in Chapter 2.3, we expect to see lower aircraft utilization for all-cargo carriers, specifically for integrated freight companies, than for combination carriers because of operational differences.

3.1.2 Financial Data

The BTS financial data include total operating expenses, depreciation costs, amortization costs, and aircraft rental costs for US air carriers. Depreciation, amortization, and aircraft rental costs were gathered from BTS Form 41, schedule P-5.2. These costs represent the expenses an airline pays to maintain their capital equipment (aircraft) for cargo operations. BTS Form 41, schedule P-1.2 provided total operating expenses. However, these data included transport related

expenses and passenger service expenses. These two expenses were removed from the data for this analysis because they are not expenses occurred during cargo operations, as explained in Section 2.4.3. Please refer to Section 2.4.3 for a more detailed analysis and description of operating cost data for all-cargo and combination carriers.

Additionally, the operating expenses reported for combination carriers must be adjusted to account for only the expenses related to cargo operations, as mentioned in Section 2.4.3. Several methods of allocating operating expenses for combination carriers are approved by the International Civil Aviation Organization (ICAO), such as the cargo offset method, where the cargo expenses are equal to the cargo profits, and the volume allocation method, where the ratio of available volume on a combination aircraft to the volume on an equivalent freighter aircraft is used to determine the proportion of total costs allocated to cargo operations. These methods, among other cost allocation methods, are described by Morrell in *Moving Boxes By Air*. The ICAO Cost Committee has recommended airlines use the volume allocation method (Morrell, 232). However, this method requires that the type of aircraft is known for each flight, an impossible requirement to satisfy with the available data from the BTS Form 41. Therefore, the method chosen for this thesis is a proportional profit-cost allocation, where the percentage of total operating expenses allocated to cargo operations is equal to the percentage of total revenue that cargo operations produce.

The proportional profit-cost allocation method is implemented using the following procedure. First, the yearly revenue generated from cargo operations for a given combination carrier is determined, along with its total annual revenue. These data were gathered from BTS Form 41, schedule P-1.2. Using these data, the percent contribution of cargo revenue is determined by dividing the cargo revenue by the total revenue. This percentage is then

multiplied by the carrier's total operating expense to approximate the carrier's expenses that are associated with cargo operations. These steps are combined into one operation, as shown in Equation 2.

$$Operating\ Expense_{Cargo} = \frac{Revenue_{Cargo}}{Revenue_{Total}} * Operating\ Expense_{Total} \quad \text{(Eq. 2)}$$

Using this correction could introduce limitations to the data analysis. As discussed in Section 2.4.3 during the analysis of combination carriers, cargo-related operations, and thus costs, have decreased significantly in the past decade. However, this modification is based on cargo revenues relative to total revenues, meaning that the size of an airline's cargo business directly affects the operating expenses used in this analysis. In other words, decreasing costs may result from a decreasing cargo business for combination carriers rather than improved cost efficiencies. This is important to remember moving forward to the productivity analyses.

3.1.3 Fuel Consumption and Fuel Cost

Fuel data collected from BTS include the total fuel consumption, in gallons, and the total fuel costs. These data are sufficient for a comparison of all-cargo carriers. However, the fuel data reported for combination carriers include fuel consumed to transport both passengers and cargo. Therefore, fuel consumption and fuel cost data for combination carriers should be weighted by the proportion of cargo carried by each combination carrier to determine the appropriate fuel consumption and fuel cost attributable to cargo operations. The weighting factor must account for both the amount of cargo carried and the distance that the cargo was carried. Thus, the factor is defined as the cargo RTMs divided by the total RTMs. This adjustment is applied as shown in Equations 3 and 4.

$$Fuel\ Consumption_{Cargo} = \frac{RTM_{Cargo}}{RTM_{Total}} * Fuel\ Consumption_{Total} \quad \text{(Eq. 3)}$$

$$Fuel\ Cost_{Cargo} = \frac{RTM_{Cargo}}{RTM_{Total}} * Fuel\ Cost_{Total} \quad \text{(Eq. 4)}$$

3.1.4 Labor Data

Labor statistics are reported in BTS Form 41 according to specific categories, such as general managers, pilots, passenger handling, cargo handling, administrative, etc. The BTS database also contains an aggregate full-time employee equivalent (FTE) statistic reported by each airline. The FTE statistic is appropriate for all-cargo carrier comparisons because the companies are dedicated to cargo operations, and therefore every employee in the company contributes in some way to producing cargo related outputs. However, combination carriers have split outputs, passenger service and cargo service. Thus, it is unclear how each employee contributes to the cargo operations. For example, the general managers of a combination carrier could make decisions regarding both passenger and cargo operations, but there is no reasonable or consistent way to determine how many FTE managers should be allocated to passenger or cargo operations. Therefore, this thesis uses only the cargo handling employees for the analysis of combination carriers. It is understood that labor productivity will appear extraordinarily high for combination carriers because the labor force used for the analysis, cargo handling employees, excludes many employees who contribute and produce cargo output. However, this analysis provides a consistent basis for combination carrier comparisons.

Additionally, total salary and fringe benefits data were collected from BTS Form 41, Schedule P-6. These data represent the cost of the labor required to produce the output, an important quantity for the multi-factor productivity analysis, which is explained below.

3.2 DEFINITION OF PRODUCTIVITY METRICS

This section describes the productivity metrics that are used to analyze productivity trends of the US air cargo industry. Two types of metrics are defined, single-factor and multi-factor. The metrics presented are applied to both all-cargo carriers and combination carriers, however, the data used to calculate the metrics differs according to the modifications described in the previous section. The single-factor productivity metrics compare the output of the US air cargo industry, RTMs or ATMs, with a single input measure such as the amount of fuel consumed, or the size of the workforce. The multi-factor productivity metric compares a single output to a combination of various inputs, effectively combining the single-factor productivity metrics.

3.2.1 Single-Factor Productivity

Formulating single-factor productivity metrics requires a clear definition of various inputs and outputs. For the air cargo industry, there are two clear output options, RTMs and ATMs. Both outputs will be analyzed in this thesis because each provides a unique insight. While ATMs provide a sense of the total capacity that a cargo carrier employs, RTMs add a sense of the carrier's ability to utilize their capacity. Inputs, on the other hand, must carefully be chosen. The Organization for Economic Cooperation and Development (OECD) describes several inputs in *Measuring Productivity*, including labor, capital, and intermediate, where intermediate inputs include energy, materials, and services (13). Using guidance from OECD's

report, this thesis analyzes four inputs for single factor productivity: operating expense, labor, fuel, and capital. Operating expense was added to gives a sense of aggregate productivity. Similarly, fuel (energy) supplants intermediate inputs because of the importance of fuel to airlines, especially in recent years as fuel coast soared; as described in Section 2.4.3, fuel expenses accounted for almost 33% of total operating expenses in 2010. Labor inputs allow an assessment of how efficiently workforce resources are utilized. Capital is defined here as the aircraft-days generated by the carrier, evaluating how effectively a carrier uses their aircraft to generate RTMs or ATMs. At the end of this section, Table 5 summarizes all of the single-factor productivity metrics used in this thesis.

Aggregate Productivity

Aggregate productivity is defined as the ability of an air carrier to transform operating expenses into outputs. As stated in the previous section, total operating expenses are used for the all-cargo carriers, but a proportional profit-cost allocation method adjusts combination carriers' costs to account only for cargo-related costs. Additionally, for a fair comparison between years, all costs were converted to constant dollars in a base year. The US consumer price index (CPI) is used as the conversion rate for a given year to translate nominal dollars into constant dollars. Common practice is to deflate all years to equivalent dollars in year zero, 1990 for this thesis. However, the author chose to use 2010 as the base year, and inflates all other years' costs to be represented in 2010 dollars. The reason for this is that using costs in present-year dollars allows for a more intuitive understanding of the dollars' value.

Another metric for assessing aggregate productivity is total aircraft utilization. This metric determines the average hours per day that an aircraft is used. Aircraft utilization is

calculated by dividing the yearly block hours by the total aircraft-days in the same year. Block hours represent the time that the aircraft spends from leaving the departure gate until the aircraft enters the arrival gate. Thus, this time includes any delays incurred while the plane sits on the runway. This thesis only applies this metric of aggregate productivity to the all-cargo carriers. The data provided in BTS Form 41 were not specific enough to determine what part of the combination carriers' utilization should be attributed to cargo operations. However, Belobaba et. al describe combination carrier utilization in *The Airline Industry* (7), and further analysis can be found in *Productivity Trends in the U.S. Passenger Airline Industry: 1978-2010.*

Labor Productivity

Labor productivity measures determine how effective a carrier is at producing outputs from the given labor inputs, such as total employees or work hours. The metric employed in this thesis is calculated by dividing the output quantity of a given year by the number of full-time equivalent employees (FTEs) for the same year. As discussed above, different labor statistics are used for all-cargo and combination carriers. The labor productivity metric for all-cargo carriers uses a total FTE statistic, whereas combination carriers are analyzed using only the cargo handling employees.

Fuel Productivity

This thesis uses two fuel productivity metrics to assess carriers' efficient use of fuel resources. The first metric makes use of carriers' fuel costs as an input, calculated as ATMs or RTMs per fuel expense. Similar to the aggregate productivity metric, the US CPI was used to inflate all fuel costs to constant 2010 dollars. It is important to note, however, that fuel is a free market commodity; thus, many extraneous factors affect the cost of fuel resulting in

unpredictable volatility. Therefore, it is difficult to attribute changes in this first fuel productivity metric to specific causes. Thus, the second productivity metric uses the gallons of fuel consumed by a carrier as the input, excluding any price fluctuations that may artificially affect the fuel cost productivity metric. This fuel consumption metric is calculated by dividing the carriers' system ATMs or RTMs by the total gallons of fuel consumed in a given year.

Aircraft Productivity

Aircraft productivity measures the effectiveness in which a carrier utilizes their capital assets (aircraft). This productivity metric is measured by dividing the ATMs or RTMs by the total number of aircraft-days reported by a carrier in a given year. It is important to note that the network structure of individual carriers affects these aircraft productivity metrics. For instance, if a carrier operates a hub-and-spoke network to consolidate and sort cargo before redistribution, the carrier will have a greater number of short-haul flights, resulting in lower aircraft utilization and, thus, lower aircraft productivity. This is the case for many integrators, such as FedEx and UPS. However, if a carrier is more dedicated to long-haul, international flights, that carrier's aircraft utilization will be higher, and the aircraft productivity should be greater.

Table 5. Single-Factor Productivity Metrics

	All-Cargo Carrier	**Combination Carrier**
Output	*RTM, ATM*	*RTM, ATM_{cargo}*
Aggregate	*Output / OPEX*	
	Block Hours / Day	–
Labor	*Ouput / FTE*	*Output / $FTE_{cargo\ handling}$*
Fuel Expense	*Output / FuelExp*	*Output / $FuelExp_{cargo}$*
Fuel Consumption	*Output / Gallons*	*Output / $Gallons_{cargo}$*
Aircraft (Capital)	*Output / Aircraft–Days*	

3.2.2 Multi-Factor Productivity

Productivity literature describes two common multi-factor productivity (MFP) metrics. Apostolides describes these two metrics in his 2008 report for the BTS as the basic growth-accounting method and the Tornqvist index (BTS 2008, 1). Robert Solow's residual method for describing economic growth in the 1950s serves as the foundation of the basic growth-accounting methodology. On the other hand, the Tornqvist method is based on the economic indexing work of Leo Tornqvist in the 1930s. Apostolides compared these two methods in his 2009 study of MFP in the US trucking industry, concluding that there were very minor differences in the results and that the two methods are "good substitutes for each other" (Apostolides 2009, 10). Therefore, this thesis uses the basic growth-accounting method to examine MFP in the US air cargo industry because it provides the reader with an easy-to-understand and transparent calculation.

The basic growth-accounting method compares the combination of several inputs to the change in a single output, determining a residual value that represents the technological progression, or digression, not attributable to any of the inputs. As applied to the US air cargo industry, the basic growth-accounting methodology can be written mathematically as,

$$\frac{\Delta T}{T} = \frac{\Delta Q}{Q} - [\left(\alpha \frac{\Delta Labor}{Labor}\right) + \left(\beta \frac{\Delta Capital}{Capital}\right) + \left(\gamma \frac{\Delta Intermediate}{Intermediate}\right) + \left(\delta \frac{\Delta Fuel}{Fuel}\right)] \quad \text{(Eq. 5)}$$

Where:

$\frac{\Delta T}{T}$ = Growth of MFP

$\frac{\Delta Q}{Q}$ = Growth of gross output

$\frac{\Delta Labor}{Labor}$ = Growth of labor input

$\frac{\Delta Captial}{Capital}$ = Growth of capital input

$\frac{\Delta Intermediate}{Intermediate}$ = Growth of intermediate input

$\frac{\Delta Fuel}{Fuel}$ = Growth of fuel input

α = Share of labor cost in input

β = Share of capital cost in input

γ = Share of intermediate cost in input

δ = Share of fuel cost in input

This thesis presents the calculation using two different time periods to calculate the growth of MFP, year-on-year and cumulative since 1991. The year-on-year analysis calculates the growth of the inputs, output, and MFP for adjacent years. For example, the growth of fuel input for 1995 would be calculated as the difference in fuel input required between 1995 and 1994. The second time period, cumulative, calculates the growth of the inputs, output, and MFP

back to 1991. This means that the fuel input growth for 1995 is calculated as the difference in fuel input required between 1995 and 1991.

The data described in the previous two sections constitute the input and output quantities used in this methodology. Apostolides describes that either real quantity terms or dollar values should be used as the input and output quantities (BTS 2008, 2). This thesis employs quantity terms for input and output growth terms to the fullest extent possible, with the exception of intermediate inputs because no single quantity term exists to represent the broad intermediate input category. Therefore, this thesis uses the change in intermediate costs, where the intermediate costs denote a catch-all category, as described in Section 2.4.3. The labor input uses full-time equivalent employees for all-cargo carriers and cargo handling employees for combination carriers. Capital input uses aircraft-days for all-cargo carriers and combination carriers, and the fuel input uses consumed gallons of fuel for all-cargo carriers and payload-weighted consumed gallons of fuel, as described in the previous sections, for combination carriers. Output growth uses either RTM or ATM for all-cargo carriers, and RTM or adjusted cargo ATM for combination carriers.

Using quantity terms minimizes any external effects, such as differences in prices obtained for fuel purchases, aircraft contracts, and labor contracts between different airlines. Arguably, the ability for an airline to achieve lower purchasing prices for these categories represents a type of productivity in their firm. However, this methodology captures this gain in productivity because the weighting scheme captures the relative importance of each input quantity, shown as α, β, γ, and δ in Equation 5. For instance, if an airline pays less for fuel than a competitor, the weight of fuel in Equation 5, represented by δ, for the first airline will be lower than the weight of fuel for the competitor. Therefore, the weighting scheme would place less

emphasis on the amount of fuel burned and accounts for any productivity gain achieved by obtaining better prices for services.

There are several other special considerations given to the weighting scheme in this methodology. The weights, defined as cost shares, represent the percentage of total OPEX for each respective input; recall that costs for combination carriers are adjusted according to the proportional profit-cost allocation method described in Section 3.1.2 Financial Data. The introduction of financial data requires normalizing all dollars to a base year, and, as explained in Section 3.1 Data Availiability, all costs are inflated to 2010 dollars.

For the year-on-year MFP calculation, the weights change to correspond to the appropriate year. For example, the appropriate costs in the year 2005 are used to calculate the weights for the MFP calculation in 2005. Moving the weights assures that appropriate effects of price changes are captured over long periods of time, such as the rising cost of fuel over the past decade. In the case of fuel costs, moving the weights appropriately places more importance on the fuel input in years when fuel costs are higher. Similarly, if an airline renegotiated labor contracts to reduce salaries, moving the weights would capture the reduced importance of labor input.

However, for the cumulative MFP calculation, two weighting schemes are utilized. Primarily, moving weights are used for this thesis to capture the evolution of input cost shares over the past 20 years. The weights are inflated to 2010 dollars, as discussed above. Constant weights, where the weights correspond to the relative cost shares in 1992, also are included in the analysis to show the contrast between MFP calculations if the relative importance of input values remained constant over time. For example, the recent increase of fuel prices in the late 2000s

has emphasized the importance of fuel consumption for cargo carriers. Without an increased emphasis on fuel inputs in recent years, we expect to see a higher productivity in the late 2000s when MFP is calculated using the constant 1992 input weights rather than the moving input weights.

3.3 CHAPTER SUMMARY

This chapter began with an introduction of the data used in this thesis. All of the data used in the productivity analyses are gathered from the US Bureau of Transportation Statistics Form 41. Traffic data, operating expense data, fuel consumption and fuel cost data, and labor statistics were gathered for all-cargo and combination carriers. ATMs, operating expenses, fuel consumption and fuel cost data were adjusted for combination carriers to account for only the portion of the data attributable to cargo operations. Additionally, rather than using a full-time equivalent employee statistic for combination carriers, only cargo-handling employees were included. These modifications to combination carrier data have limitations, as discussed above, but they provide a consistent basis for year-to-year comparisons of productivity.

After presenting the data, productivity metrics were introduced. This thesis utilizes two types of productivity metrics, single-factor productivity (SFP) and multi-factor productivity (MFP). These metrics are applied to both all-cargo carriers and combination carriers; however, the data used to calculate the metrics differs according to the modifications discussed above. SFP metrics compare a given output to a single input. In this thesis, ATMs and RTMs represent air cargo outputs while FTEs, fuel consumption and fuel costs, aircraft-days, and total OPEX represent air cargo inputs. The MFP metric compares a single output, either ATMs or RTMs, to

a combination of inputs, effectively combining the SFP metrics. MFP is calculated using year-on-year (y-o-y) growth and cumulative growth of inputs and outputs from 1992 to 2010. For the y-o-y MFP calculation, only moving input weights are used, while both constant 1992 input weights and moving input weights are used for the cumulative MPF calculation. The following chapter will present the productivity results for all-cargo carriers and combination carriers based on the methodology presented above.

4. US AIR CARGO PRODUCTIVITY RESULTS

Chapter 2 explored the background of the US air cargo industry, providing traffic statistics since 1983 and operating expense data since 1990 for all-cargo carriers and combination carriers. These data were described and major events were explained, including the entrance and exit of airlines in the industry during the past 20 years, the September 11th terrorist attacks, and the fuel price increase in the late 2000s. Chapter 3 continued to describe the available data before presenting the productivity methodology for this thesis. This chapter presents the productivity results, using the context provided in Chapter 2 to help explain productivity changes during the past two decades. Single-factor productivity results are discussed first, followed by multi-factor productivity results. Each section of results is separated into two parts, one for all-cargo carriers and one for combination carriers.

4.1 SINGLE-FACTOR PRODUCTIVITY METRICS

4.1.1 All-Cargo Carriers

This section presents the single factor productivity trends for US all-cargo carriers from 1990 to 2010. Six different metrics explore productivity, including: aggregate productivity, daily aircraft utilization, aircraft productivity, fuel consumption productivity, fuel expense productivity, and labor productivity. These metrics are explained in detail in Section 3.2.1. The following list shows the all-cargo carriers included in the data used for this analysis, representing approximately 92% of the US all-cargo industry in terms of ton-mile traffic. Please refer to Section 2.4.3 for a more detailed description of these carriers.

1. United Parcel Service (UPS)
2. Atlas Air Inc.
3. Air Transport International
4. Southern Air Inc.
5. ABX Air, Inc.
6. Evergreen International Inc.
7. Federal Express Corporation (FedEx)
8. Kalitta Air LLC
9. Polar Air Cargo Airways
10. Emery Worldwide Airlines
11. Centurion Cargo Inc.

This report analyzes data for UPS and FedEx separately from the other nine all-cargo carriers listed above for the single-factor productivity analysis (this section) and for the multi-factor productivity analysis (Section 4.2). The decision to perform a separate analysis stems from the distinct operational differences of UPS and FedEx, which operate as vertically integrated freight carriers, whereas the other nine carriers tend operate with chartered services. In other words, FedEx and UPS transport their own cargo according to their own service schedule while the other all-cargo carriers wait to accept cargo from a customer. This does not mean that the other all-cargo carriers operate without a schedule, but rather that their customers influence the schedule and operations. Additionally, UPS and FedEx are the top two US all-cargo carriers and account for 60%-89% of the total US all-cargo RTMs carried during the 20 year analysis period.

Vertically integrated operations, as described in Sections 2.2 and 2.3, integrate all operations of freight carriers – trucking, air carriage, and freight forwarding. As a result, these companies rely on consolidated services at a major hub, such as Memphis, Tennessee for FedEx. Furthermore, the integrated business model requires adherence to a strict service schedule, where

aircraft converge on the hub at night to sort, consolidate, and redistribute the cargo onto other aircraft. These aircraft then depart in the early morning to the destination airports, where ground trucks in a distribution network deliver the cargo to the final destination. During the day, the aircraft wait to collect cargo before departing back to the hub in the evening. This schedule constrains operational characteristics, such as aircraft utilization, and affects productivity metrics for the carriers, which is discussed in further detail below.

Aggregate Productivity

An aggregate measure of productivity is the first single-factor metric used to assess the US air cargo industry for all-cargo carriers. Figure 18 and Figure 19 show the trends of aggregate productivity for FedEx/UPS and the other all-cargo carriers, respectively, over the past two decades for two output values, revenue ton-miles (RTM) and available ton-miles (ATM). The input quantity, total operating expense (OPEX) excluding transport related expense, is shown in terms of 2010 dollars.

Aggregate productivity for FedEx and UPS has remained relatively constant since 1990, with a minor decrease occurring during mid-2000s as fuel costs increased, raising total OPEX. ATM aggregate productivity for FedEx and UPS has remained around 1.7 ton-miles per dollars of OPEX, achieving only a 6% growth during the past 20 years. Similarly, RTM aggregate productivity has hovered around 1.0 ton-mile per dollar, with an 11% growth over the past 20 years. The constant nature of aggregate productivity for FedEx and UPS results from operating expenses increasing proportionally to increases in traffic, ATMs and RTMs, over the past 20 years.

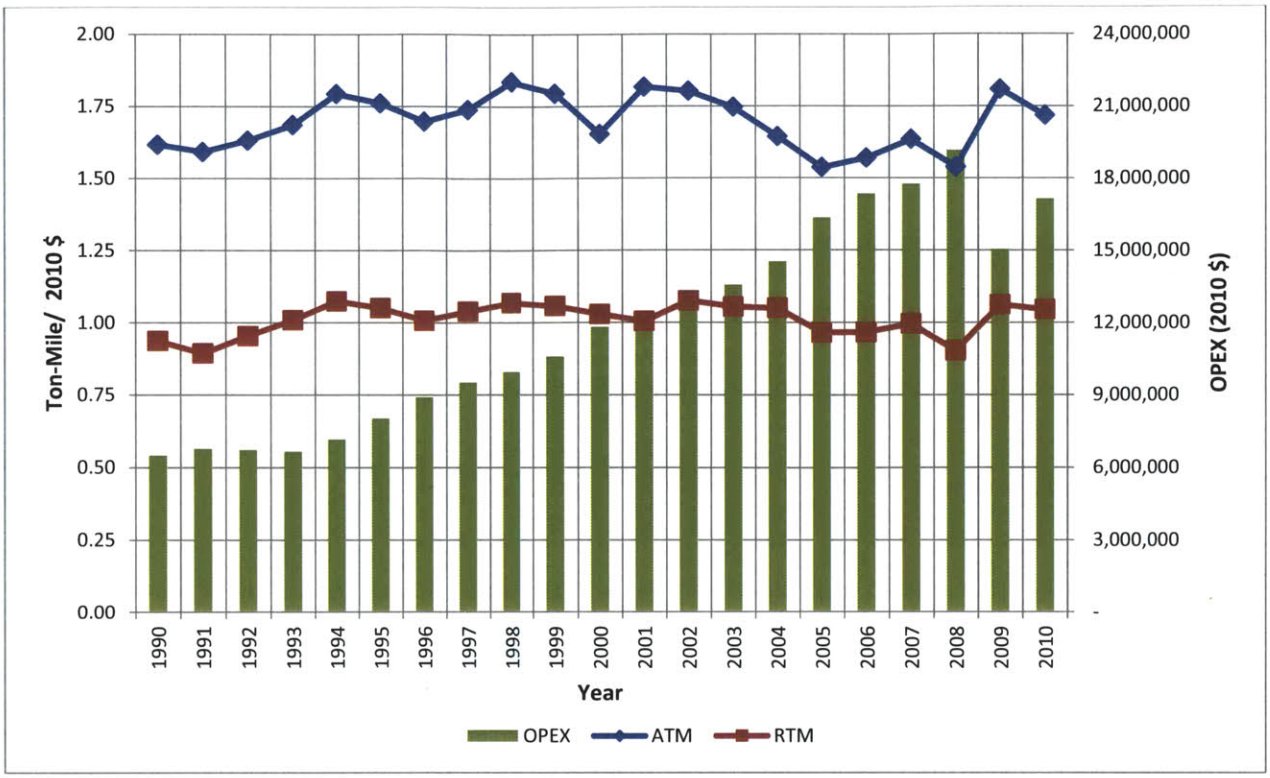

Figure 18. FedEx and UPS Aggregate Productivity

Alternatively, the other all-cargo carriers have experienced a different aggregate productivity trend over the past 20 years, as shown in Figure 19. Aggregate productivity for the other all-cargo carriers experienced quick growth through the first half of the 1990s. After the growth, ATM productivity remained constant near 3.5 ton-miles per dollar of OPEX and RTM productivity steadied around 2.25 ton-miles per dollar of OPEX until the end of the decade. Both ATM and RTM aggregate productivity grew quickly for the other all-cargo carriers in the first few years of the 21st century, reaching levels above 5.5 ton-miles per dollar and 3.5 ton-miles per dollar, respectively.

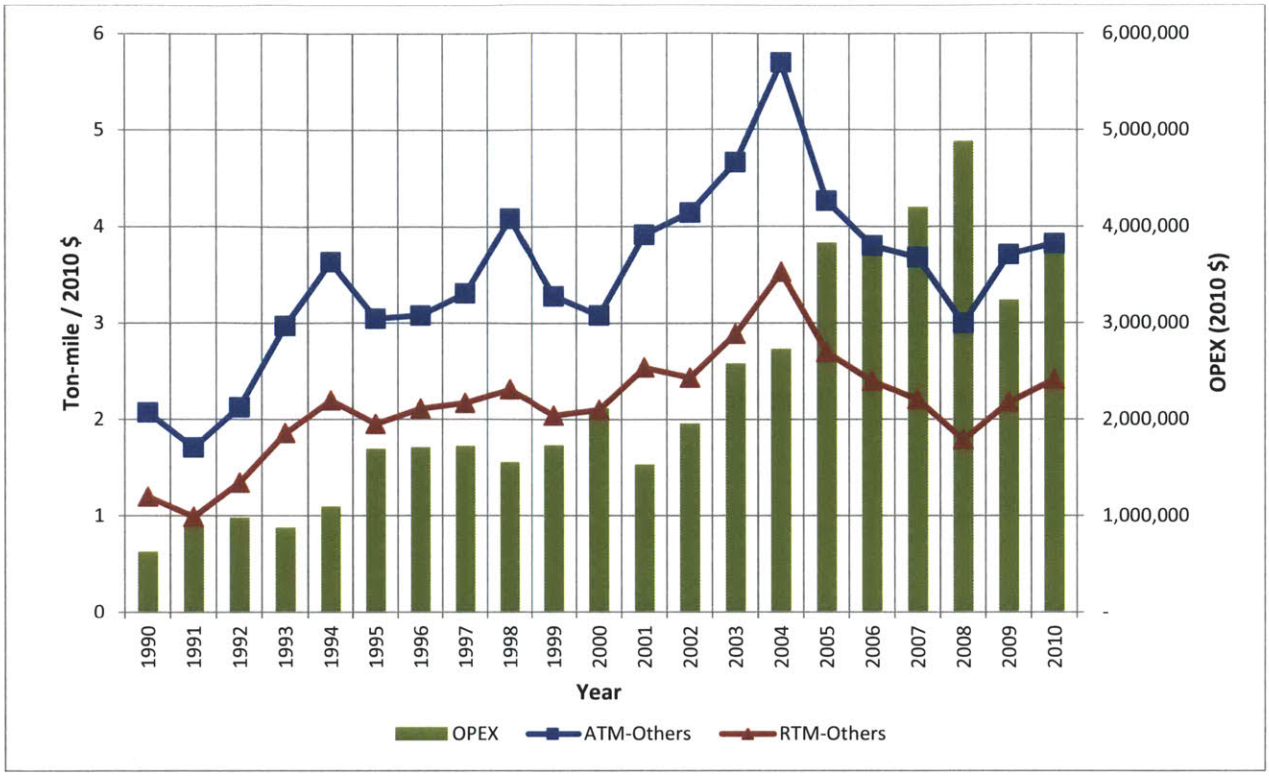

Figure 19. All-Cargo Carrier Aggregate Productivity

Operating expenses grew rapidly in the middle of the 2000s with the rise in fuel prices and the economic downturn in 2008, causing declines in aggregate productivity back to levels near the start of the 2000s. Part of the growth and decline of productivity in the early and mid-2000s resulted from the exit of Emery Worldwide in 2001 and the entrance and growth of ABX Air in 2003. When Emery Worldwide exited the air cargo industry, total OPEX decreased quicker than total traffic causing an apparent increase in productivity. Similarly, when ABX Air entered in the mid-2000s, total OPEX increased faster than total traffic for the next few years, causing a decrease in productivity.

Aggregate productivity grew slightly through 2009 and 2010, ending at 3.8 ton-miles per dollar for ATMs and 2.4 ton-miles per dollar for RTMs. These values represent a total growth of

85% for ATM aggregate productivity and 102% for RTM aggregate productivity over the past two decades. The other all-cargo carriers have achieved this productivity growth by increasing traffic over the past decade, capturing some market share from FedEx and UPS, and by adopting new technology to decrease fuel consumption and fuel expenses and to decrease labor requirements and expenses – decreasing the required OPEX to produce a given amount of output. These topics will be explained in more detail in the following sections.

Aircraft Productivity

This section uses two measures of aircraft productivity to assess all-cargo carriers. The first, and more common, measure in the airline industry is aircraft utilization, defined in terms of block hours per day. Figure 20 shows the trend of all-cargo aircraft utilization during the past two decades. Aircraft utilization for FedEx and UPS has remained relatively constant for the past 20 years, hovering between 3 and 3.5 hours per day. The other all-cargo carriers have seen a more cyclical trend in aircraft utilization from 1991 to 2010. One peak occurred in the early 1990s as a result of booming cargo traffic following the mini-recession in 1990. The second peak occurred in 2002, but questionable data reporting by all-cargo carriers raises uncertainty about the validity of this spike in aircraft utilization; a gray-shaded box identifies the questionable data reported in Figure 20.

Recall from Section 2.4.3 that Emery Worldwide exited the industry in 2001. At that time, Emery accounted for nearly 45% of total block hours flown and 33% of total aircraft-days. In 2002, the total block hours reported by all cargo carriers remained approximately constant but the reported aircraft-days decreased in Emery's absence. The reported data remained

questionable until 2005 when ABX Air began expanding their business and the all-cargo carrier aircraft utilization returned to approximately six hours per day.

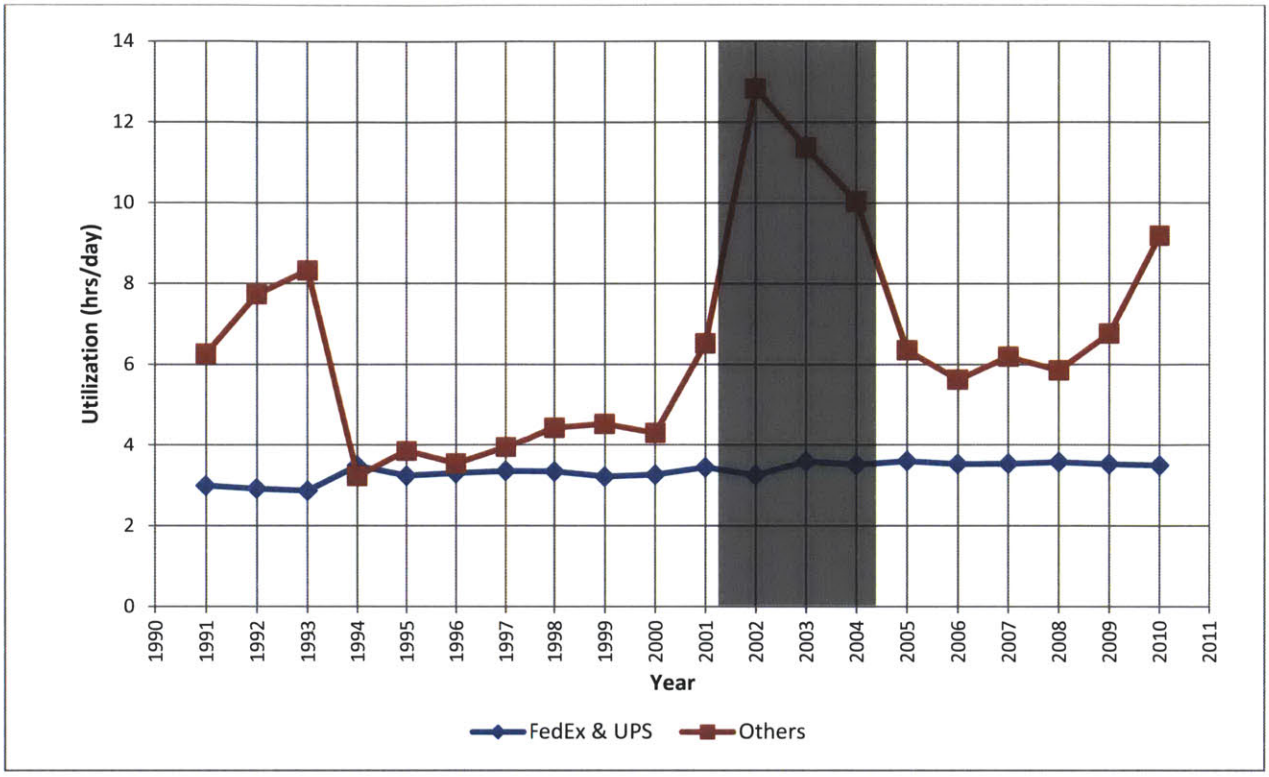

Figure 20. All-Cargo Carrier Aircraft Utilization

It is important to note that the other all-cargo carrier aircraft utilization is approximately 2.5 hours per day more than FedEx and UPS since 20005. This disparity in aircraft utilization is a result of several factors. First, the network structure and average stage length of flights affects aircraft utilization. Longer stage lengths typically mean greater aircraft utilization. It is well known that FedEx and UPS operate many short-haul flights to and from their hubs to sort and consolidate cargo as much as possible, whereas other carriers may accept long-haul flights with less consolidated cargo. Second, aircraft scheduling and route planning can have a profound effect. A schedule plan that prevents long periods of aircraft waiting at airports increases aircraft

utilization. The crux of FedEx's and UPS's operations necessitates long ground times at airports. As explained in Section 2.2, FedEx and UPS consolidate cargo as much as possible by collecting freight at the airport during the day. In the evening, the plane departs back to the central hub airport where it is sorted and loaded on a plane to the destination airport for the next morning. Upon delivery in the morning, the plane waits throughout the day, repeating this pattern. These operations result in few flights per day and low fleet-average aircraft utilization.

A second metric defined as RTMs, or ATMs, per aircraft-days also represents aircraft productivity. Figure 21 and Figure 22 show the trend of this aircraft productivity for FedEx/UPS and the other all-cargo carriers, respectively, throughout the past two decades. The trend is overlaid on the evolution of aircraft-days during the same time period. This productivity metric has grown significantly for FedEx/UPS over the past two decades. In 1990, aircraft productivity was around 54,000 ATM per aircraft-day and 30,000 RTM per aircraft day. These measures have risen to 92,000 ATM per aircraft-day and 56,000 RTM per aircraft-day, representing a 70% growth and an 87% growth, respectively.

Contrary to FedEx/UPS, the other all-cargo carriers have experienced a more cyclical aircraft productivity metric evolution during the past 20 years. Aircraft productivity decreased by approximately 55% in 1994, grew over 300% from 2000-2002, and decreased 60% from 2004-2006. However, as discussed in Section 2.4.3, Polar Air Cargo and Atlas Air entered the all-cargo industry in 1993, Emery Worldwide Airlines' fleet was grounded in 2001, and ABX Air entered the all-cargo industry in 2003 – all of these events align with significant spikes in reported aircraft-days. While no extreme spikes in ATMs or RTMs occurred in 1993, the entrance of Polar Air Cargo and Atlas Air caused a rapid increase in aircraft-days flown, which caused the dramatic drop in aircraft productivity.

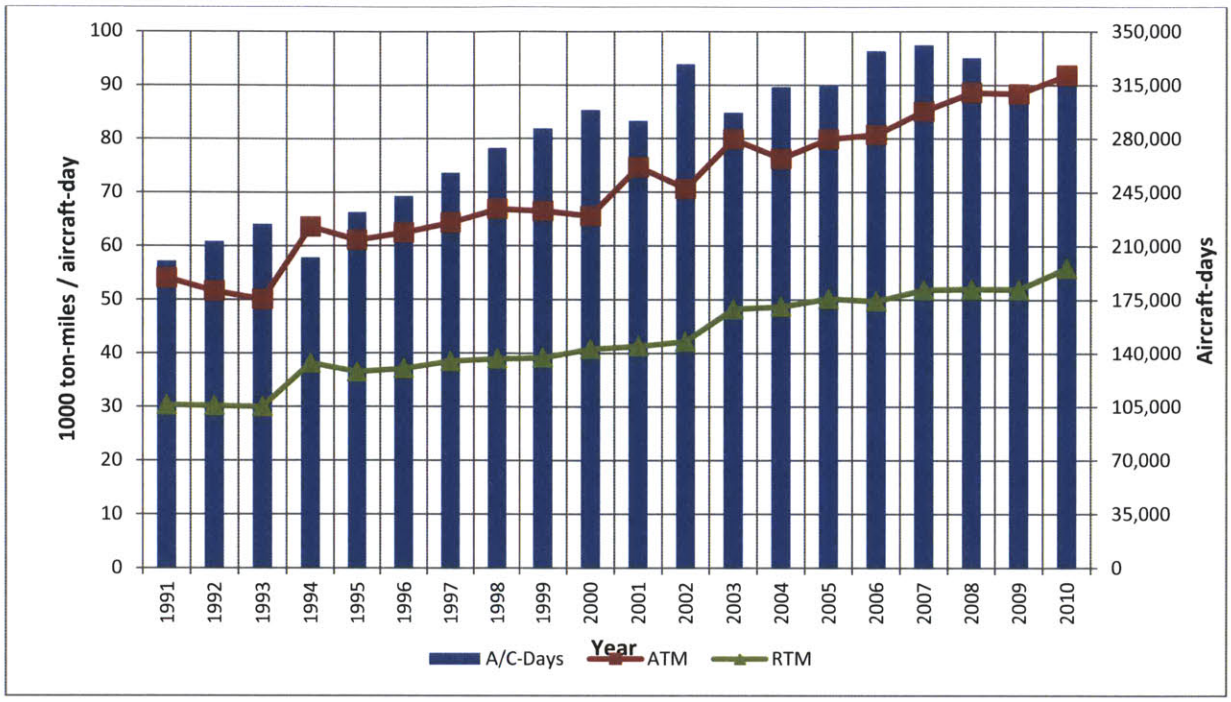

Figure 21. FedEx and UPS Aircraft Productivity

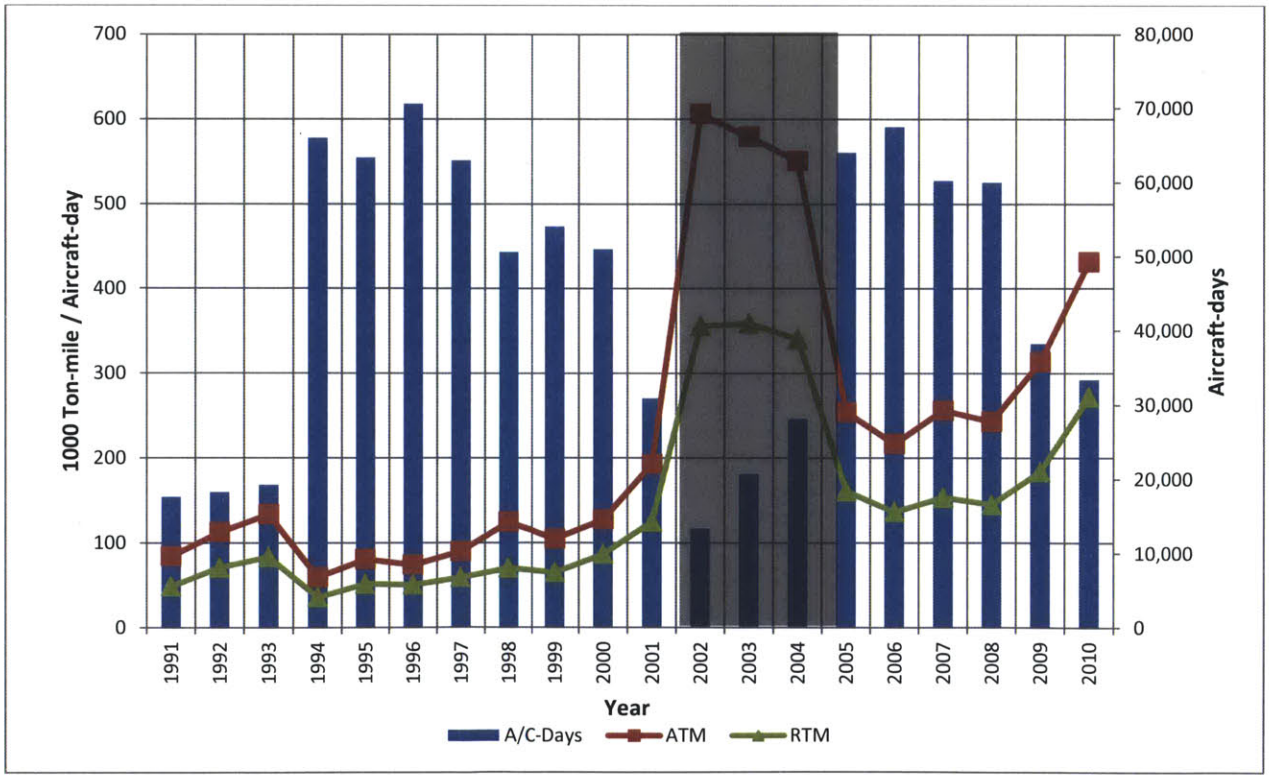

Figure 22. All-Cargo Carrier Aircraft Productivity

Similarly, the exit and entrance of airlines in the early 2000s precipitated the large apparent increase and decrease, respectively, in aircraft productivity. As explained above for aircraft utilization, when Emery exited the industry in 2001, aircraft-days decreased around 50%. From 2002 to 2004, the reported aircraft-days appear disproportionally low for the reported traffic and capacity. However, when ABX Air grew in 2005, the total aircraft-days reported returned to a reasonable level, consistent with reported traffic data. A gray box on Figure 22 highlights the questionable data between 2002 and 2004.

Absent these events, the other all-cargo carriers experienced consistent aircraft productivity growth during the past 20 years. ATM aircraft productivity has grown approximately 410% since 1991, and RTM aircraft productivity has grown 455%. However, most of this growth occurred from 2009-2010 when aircraft-days were cut by approximately 40%, causing aircraft productivity nearly to double. ABX Air's traffic decrease during 2009 and 2010 caused most of the aircraft-day decrease. From 2008 to 2010, ABX Air's aircraft-days declined 77% as DHL decided to cut US domestic traffic, which was ABX's largest service (Morrell, 103). Additionally, load factor increased during these two years, contributing to the decrease in aircraft days because each aircraft carried more freight, decreasing the need for additional aircraft.

Fuel Productivity

The first metric used for the fuel productivity analysis compares either the produced or consumed output, ATM or RTM, with the amount of fuel consumed by the aircraft used to generate the output. Figure 23 and Figure 24 show the trends of the fuel consumption

productivity metric for FedEx/UPS and the other all-cargo carriers, respectively for both ATM and RTM output, along with the amount of fuel consumed during each year.

Fuel consumption for FedEx/UPS increased from approximately 800 million gallons in 1991 to almost 1.8 billion gallons in 2005, a 110% growth during the 14 year period. During the past five years, fuel consumption has hovered around 1.8 billion gallons per year, peaking at 1.9 billion gallons in 2007 before decreasing to 1.7 billion gallons in 2009 during the economic recession. The stabilization of total RTMs, as explained in Section 2.4.3-US Trends, explains why total fuel consumption growth slowed during the past five years; the total fuel consumption will remain approximately constant if the total cargo traffic remains constant.

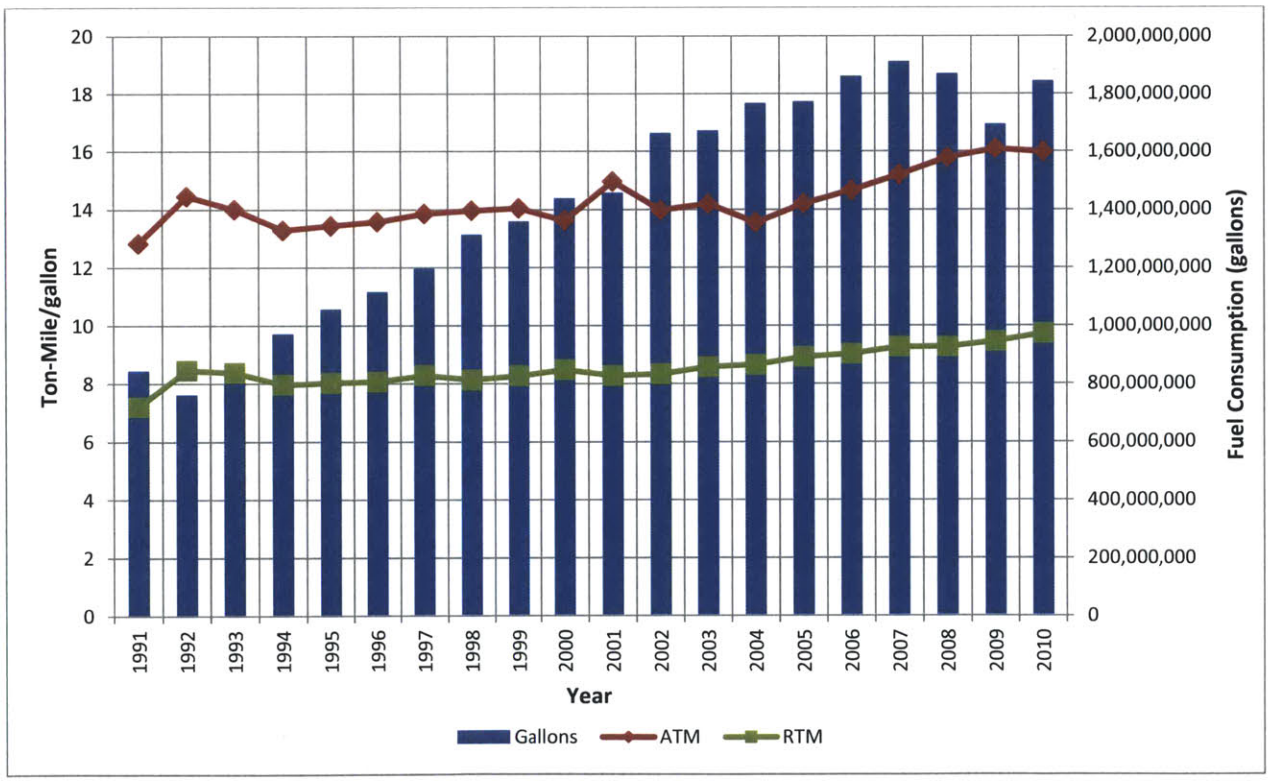

Figure 23. FedEx and UPS Fuel Consumption Productivity

Even with significant growth in total fuel consumption for FedEx/UPS from 1991 to 2010, fuel consumption productivity grew during the past 19 years because traffic figures, ATMs and RTMs, grew faster than fuel consumption. ATM fuel consumption productivity grew 25% from 12.8 to 16.0 ton-miles per gallon from 1991 to 2010, while RTM fuel consumption productivity increased 35% from 7.2 to 9.7 ton-miles per gallon during the same time period.

Fuel consumption for the other all-cargo carriers has shown a more variable trend than FedEx/UPS' fuel consumption during the past 19 years, with notable increases occurring from 1993-1995 and 2003-2004 and a notable decrease from 1999-2002. These fluctuations align with several important events as described in Section 2.4.3-US Trends. Polar Air Cargo and Atlas Air entered the industry in 1993, followed by ABX Air in 2003, triggering the increases in total fuel consumption in the early 1990s and 2004-2005, respectively; Emery Worldwide Airlines exited the industry in 2001 which contributed to the decrease in total fuel consumption as their operations declined.

Contrary to the cyclical trend of gallons consumed, fuel consumption productivity for the other all-cargo carriers experienced mostly growth during the past 19 years, with a large increase occurring from 2002 to 2003. ATM fuel consumption productivity grew from 9.6 ton-miles per gallon in 1991 to 16.6 ton-miles per gallon in 2010, a 73% growth over 19 years. RTM fuel consumption productivity grew from 5.5 ton-miles per gallon in 1991 to 10.5 ton-miles per gallon in 2010, a 90% growth over 19 years. The large increase that occurred from 2002-2003 resulted from the sudden growth of Atlas Air traffic from 2002-2003 and the introduction and growth of ABX Air beginning in 2003.

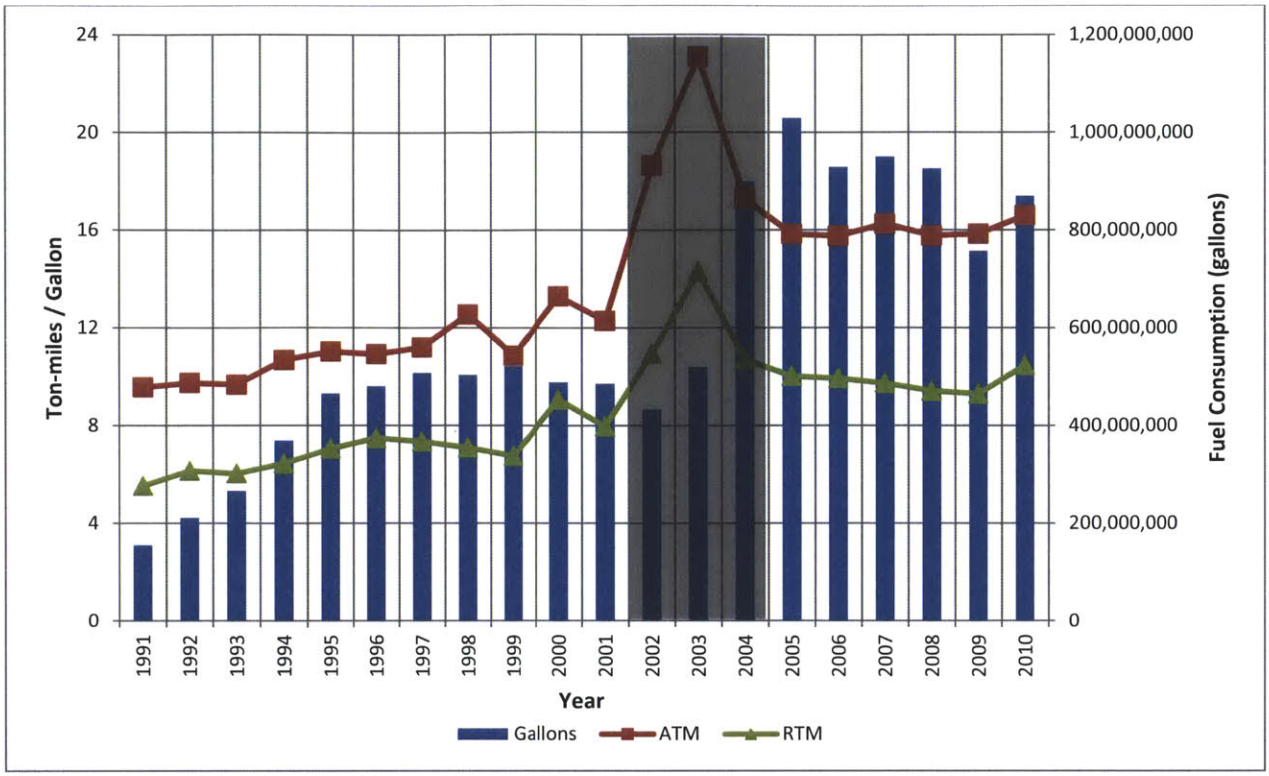

Figure 24. All-Cargo Carrier Fuel Consumption Productivity

Increased fuel efficiency in aircraft engines is likely a key driver of increasing fuel consumption productivity during the past 19 years. New technology has allowed aircraft engines to become more efficient and to reduce the specific fuel consumption, allowing the same payload to be carried while burning less fuel. Additionally, new larger aircraft entered the fleet in the mid-2000s, replacing some of the older aircraft. The larger aircraft transport more cargo with marginally less fuel consumption, adding to the increasing fuel consumption productivity realized in the late-2000s. Lastly, airlines are introducing lighter cargo containers to reduce overall weight and thus reduce fuel consumption.

Output per fuel expense serves as the second metric used to analyze fuel productivity. Figure 25 and Figure 26 provide the trends of fuel expense productivity and the fuel expenses,

expressed in 2010 dollars, for FedEx/UPS and the other all-cargo carriers, respectively, from 1990 to 2010. Unlike fuel consumption productivity, fuel expense productivity varies greatly over time because the volatile price of fuel affects this metric.

Fuel expenses were fairly constant for FedEx/UPS throughout the 1990s before increasing rapidly in the 2000s; in the early 1990s fuel expenses constituted approximately 12% of total OPEX, compared to the late 2000s where fuel represented about 25% of the total OPEX.

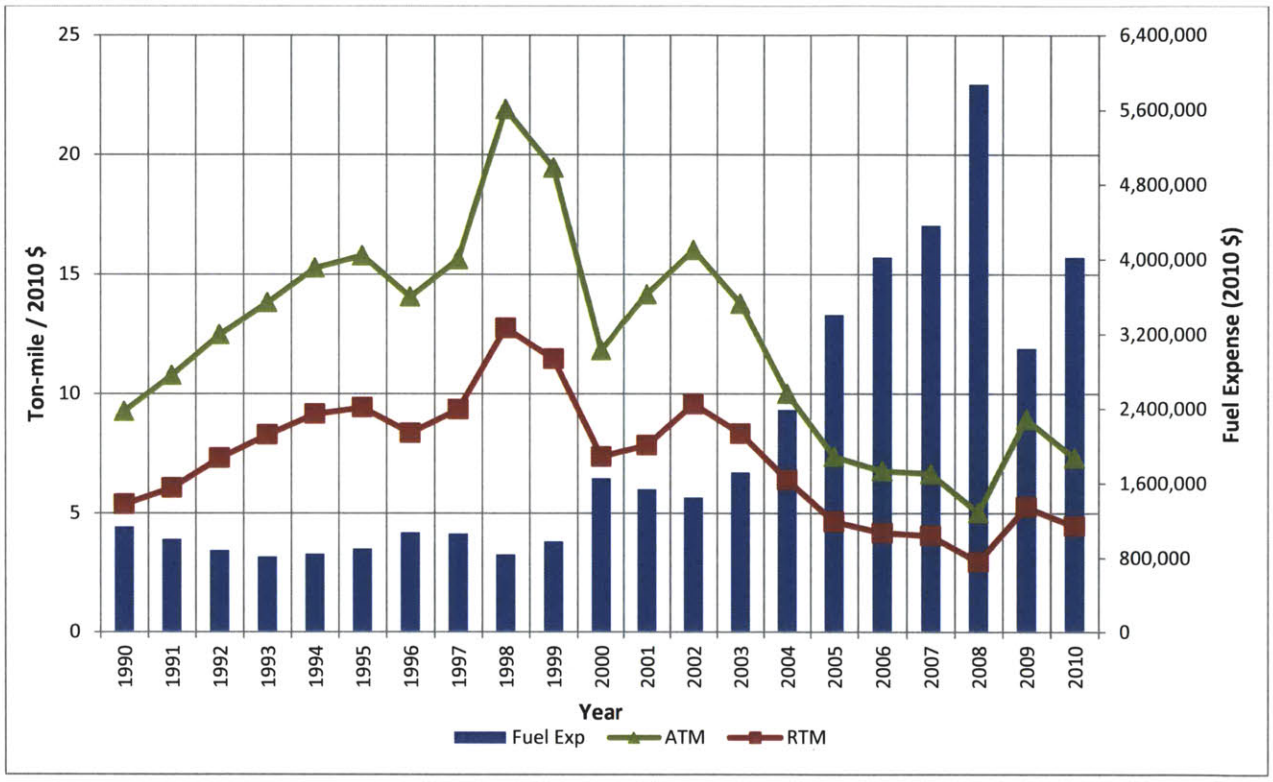

Figure 25. FedEx and UPS Fuel Expense Productivity

As the FedEx/UPS' fuel costs remained steady through the 1990s, fuel expense productivity increased because of the increase in ATM and RTM traffic during the same time period. ATM and RTM fuel expense productivity peaked in 1998 at 21.9 ton-miles per dollar and 12.8 ton-miles per dollar, respectively, representing approximately 140% growth since 1990.

However, since the price of fuel increased in the 2000s, fuel expense productivity decreased. Fuel expense productivity bottomed out in 2008, corresponding to the largest fuel expense, before rebounding slightly over the next two years. In 2010, ATM and RTM fuel expense productivity were at 7.3 ton-miles per dollar and 4.5 ton-miles per dollar, respectively. Hence, over the past two decades, the volatile and increasing fuel costs have contributed to a 21% drop in ATM fuel expense productivity and a 17% drop in RTM fuel expense productivity.

Other all-cargo carriers experienced similar fuel expense trends to FedEx/UPS. Fuel expenses remained relatively constant through the 1990s while representing approximately 12% of total OPEX in the early 1990s. Through the 2000s, fuel expenses rose from around $300 million in the early 2000s to a peak of nearly $1.8 billion in 2008. Note, however, that part of this large growth resulted from the introduction and growth of a large carrier in the mid-2000s, ABX Air. In 2010, fuel expenses represented around 36% of total OPEX for the other all-cargo carriers.

Fuel productivity for the other all-cargo carriers increased in the first half of the 1990s before decreasing continuously until 2010. ATM and RTM fuel expense productivity peaked in 1995 at 57.2 ton-miles per 2010 dollar and 36.6 ton-miles per 2010 dollar, representing a 270% increase and a 310% growth, respectively. While fuel expense productivity should have increased during this time period because ATMs and RTMs increased and fuel expenses remained approximately constant, the magnitude of productivity shown in Figure 26 seems abnormally large; a gray box indicates the questionable data in Figure 26. Fuel expense data for Emery Worldwide Airlines during this time period appears questionably low for the amount of traffic carried and block hours flown, compared to other all-cargo carriers. Since 1995, fuel expense productivity has decreased as fuel expenses have increased faster than ATM and RTM

traffic increased. In 2010, ATM fuel expense productivity was at 10.5 ton-miles per 2010 dollar, a 32% decrease since 1990, and RTM fuel expense productivity was at 6.6 ton-miles per 2010 dollar, a 26% decrease since 1990.

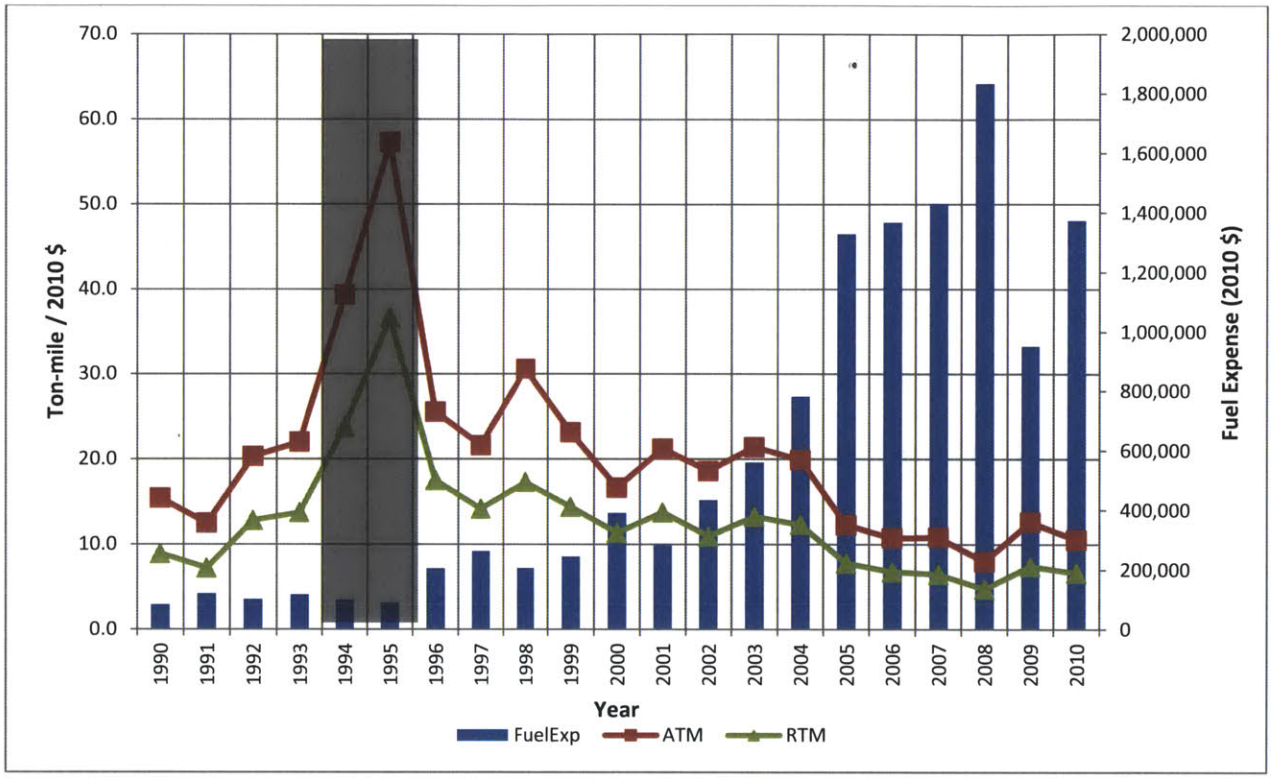

Figure 26. All-Cargo Carrier Fuel Expense Productivity

Labor Productivity

Labor productivity in the air cargo industry is explored using a metric that compares the output, ATM or RTM, to the total number of employees, measured as full-time equivalent employees. Figure 17 and Figure 18 shows the labor productivity trends and the trends of FTE employees from 1990 to 2010 for FedEx/UPS and the other all-cargo carriers, respectively. The total number of FTEs at FedEx/UPS increased from around 80,000 employees to 125,000

employees during the 1990s. However, since 2000, the total FTEs have remained approximately constant, near 120,000 employees.

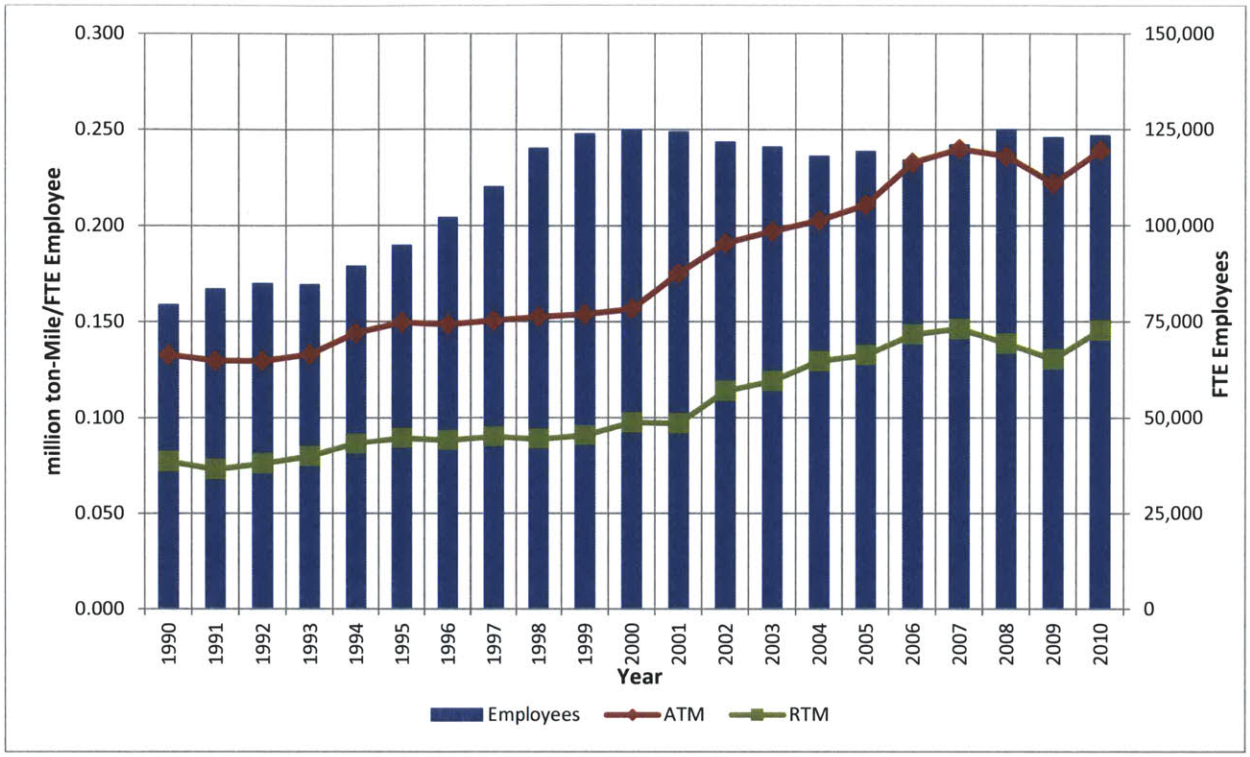

Figure 27. FedEx and UPS Labor Productivity

For FedEx/UPS, labor productivity growth was slow during the 1990s, but growth accelerated in the 2000s as a result of the FTEs remaining approximately constant. Through the 1990s, ATM labor productivity grew 18% and RTM labor productivity grew 26%. However, since 2000, ATM and RTM labor productivity each grew 50%, resulting in 20 year labor productivity growths of 80% for ATM labor productivity and 88% for RTM labor productivity. Automated systems for cargo processing and reservation systems became ubiquitous in the 2000s and drove labor productivity growth by requiring less FTEs to complete the work for FedEx/UPS. Morrell discusses these technological advancements in *Moving Boxes by Air*, noting that automation and electronic processing have reduced security clearance delay times

(154). He also discusses integrators' widespread use of computers and the internet for reservation services, providing a "single point of contact" for customers to survey all shipping options and "select the service best meeting their needs" (Morrell, 188).

Unlike FedEx/UPS, the other all-cargo carriers have experienced cyclical labor productivity growth. However, as discussed in previous sections, the entrance and exit of carriers during the past 20 years played a major role in causing the cyclical trends. FTEs grew 340% through the 1990s, with the most growth caused by Emery Worldwide's expansion during the late 1990s before they exited the industry in 2001, causing a decrease in FTEs. Another large FTE growth occurred in 2005 as a result of ABX Air's massive expansion in the mid-2000s. However, the number of FTEs reported by ABX Air dropped in 2009-2010, causing the large drop seen in Figure 18. The FTE data reported for Emery Worldwide and ABX Air during their peaks in the late 1990s and mid-2000s, respectively, appears questionable because they reported abnormally large amounts of FTEs during those years for the amount of ATMs and RTMs reported, compared to other all-cargo carriers.

Overlooking the FTE peaks in the late 1990s and mid-2000s, labor productivity for the all-cargo carriers grew during the past 20 years. ATM labor productivity grew from 720,000 ton-miles per FTE in 1990 to 3,000,000 ton-miles per FTE in 2010, a 316% growth over 20 years. During the same time period, RTM labor productivity grew 358%, from 410,000 ton-miles per FTE in 1990 to 1,890,000 ton-miles per FTE in 2010. It is worth noting that the other all-cargo carriers appear approximately 10 times more productive than FedEx/UPS. One reason for this may be that the labor statistics provided in BTS Form 41 include all of the ground handling employees for FedEx/UPS, which would significantly increase the total FTEs and reduce labor productivity.

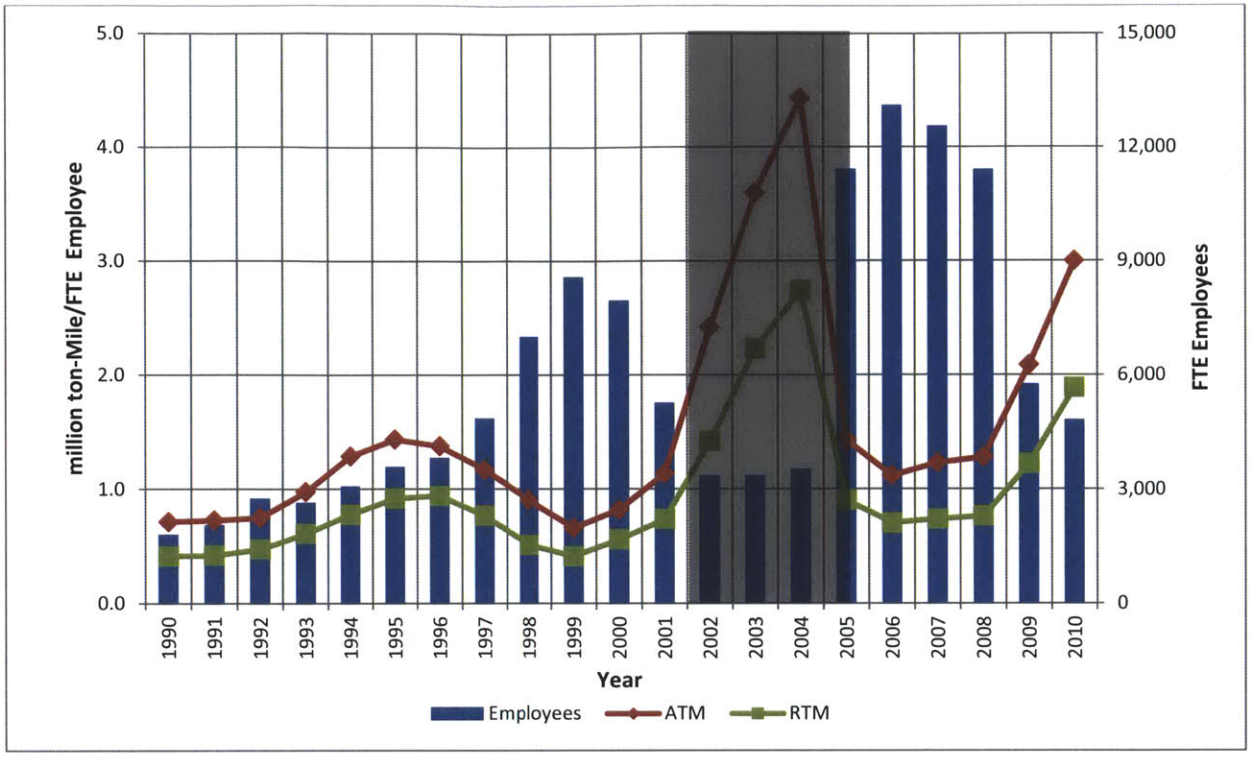

Figure 28. All-Cargo Carrier Labor Productivity

Questionable data found in BTS Form 41 makes it difficult to attribute any labor productivity growth to specific factors. However, many companies adopted technological improvements which improved labor productivity. As discussed above, automated systems have expedited cargo security screening, thus reducing delay times. Additionally, Morrell talks about the establishment of automated systems air cargo distribution systems in the early 2000s, such as the Air Cargo Community Systems (CCS) and the Global Freight Exchange (GF-X) (187). These systems eased sharing of cargo information, automated shipment tracking, and prepared airplane load sheets automatically – all of these services increase labor productivity by reducing the required FTEs or boosting the output per FTE.

4.1.2 Combination Carriers

This section presents the single factor productivity trends for US combination carriers from 1990 to 2010. Five metrics explore productivity, including: aggregate productivity, aircraft productivity, fuel consumption productivity, fuel expense productivity, and labor productivity. These metrics are explained in detail in Section 3.2.1. The following list contains the seven combination carriers included in the data used for this analysis, representing approximately 90% of the US combination carrier cargo industry in terms of ton-mile traffic. These carriers were selected based on two criteria, as described in Section 2.4.3. Cargo revenues constituted at least two percent of total operating revenues for each of these seven carriers, and cargo RTMs exceeded 10% of total RTMs carried.

1. American Airlines Inc.
2. Alaska Airlines Inc.
3. Continental Air Lines Inc.
4. Delta Air Lines Inc.
5. Hawaiian Airlines Inc.
6. Northwest Airlines Inc.
7. United Air Lines Inc.

Aggregate Productivity

Analyzing the cargo operating expenses (OPEX), excluding transport related and passenger expenses, per produced (cargo ATM) and consumed (RTM) output provides insight to the aggregate productivity trends for combination carriers from 1990 to 2010. Recall that the cargo OPEX was calculated using the offset method described in Section 3.2.2 Financial Data and ATMs were adjusted to account for cargo ATMs only, as described in Section 3.2.1 Traffic Data. Figure 29 shows the trends of aggregate productivity and cargo OPEX over this time

period. Cargo OPEX for combination carriers dropped from around $3 billion in the early 1990s to around $1.7 billion in 2010. However, cargo OPEX has remained relatively steady for most of the past 20 years, hovering around $2.5 billion, in terms of 2010 dollars. Cargo ATM aggregate productivity rose 113% through the 1990s and the early 2000s, from 7.1 ton-miles per dollar to just over 15.1 ton-miles per dollar. However, the economic downturn in 2008 coupled with extremely high fuel prices precipitated a decline in cargo ATM aggregate productivity. In 2009, productivity levels rebounded as cargo OPEX dropped nearly one billion dollars when large NLCs, such as Northwest Airlines and American Airlines reduced their cargo operations[3]. Since 1990, cargo ATM aggregate productivity has increased 153% to 18 ton-miles per dollar.

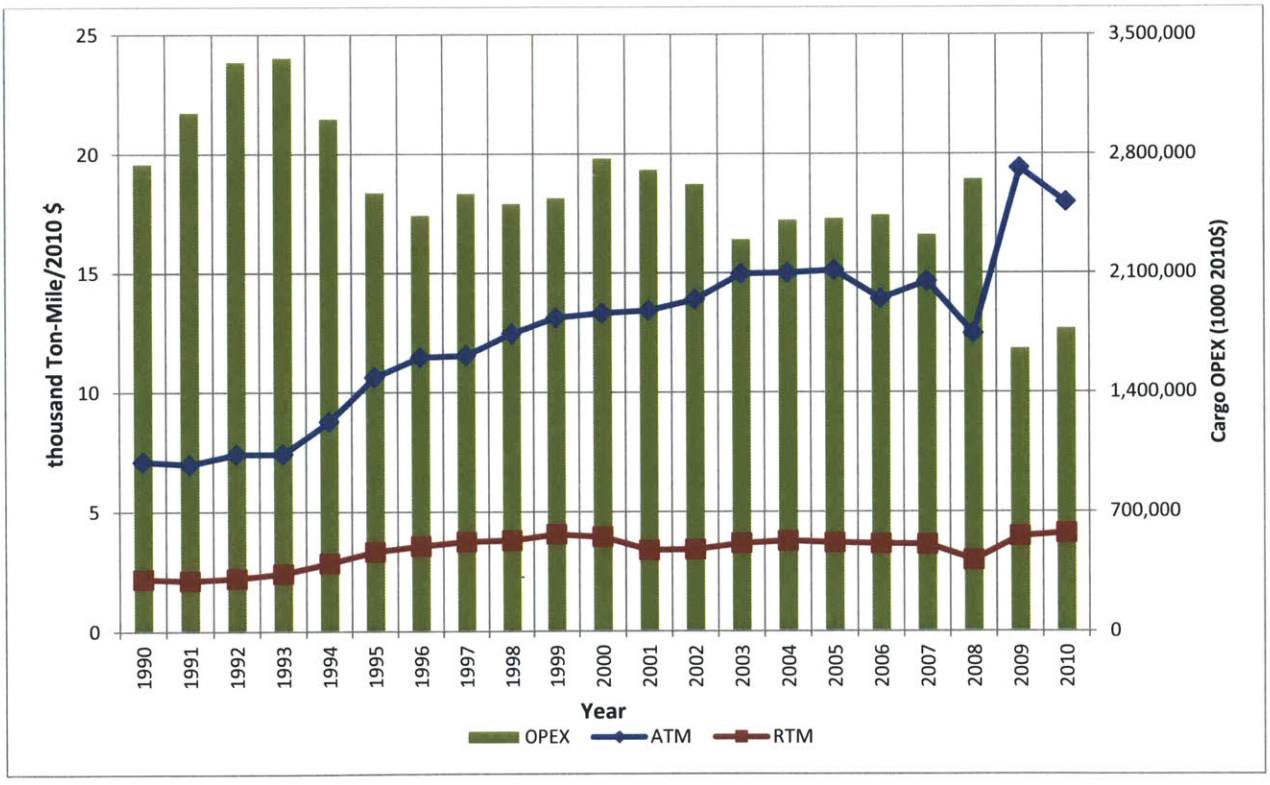

Figure 29. Combination Carrier Aggregate Productivity

[3] Recall from Section 3.1.2 that cargo OPEX is proportional to total cargo revenues. Therefore, when NLCs reduced their cargo operations, cargo revenues fell and, thus, cargo OPEX decreased.

Aggregate productivity for consumed output, RTMs, reveals a slightly different pattern. RTM aggregate productivity increased 83% throughout the 1990s, from 2.2 ton-miles per dollar in 1990 to four ton-miles per dollar in 2000. RTM productivity realized a drop in 2001 as a result of decreased combination carrier traffic following the economic recession in the early 2000s and the terrorist attacks on September 11, 2001. Since 2001, RTM aggregate productivity has decreased steadily, reaching a trough in 2008 before increasing back to 2000 levels during 2009 and 2010. Over the past two decades, RTM aggregate productivity has increased only 88%.

There are several noteworthy factors that explain why combination carrier RTM aggregate productivity did not grow in the same manner as cargo ATM aggregate productivity from 1990 to 2010. Following the terrorist attacks in 2001, the Transportation Security Administration (TSA) enforces the 9/11 Act which strengthened security regulations in 2007 required intensive screening cargo on passenger flights operated by commercial airlines (Morrell 170). The additional screening regulations increased the workload and responsibility for combination carriers because they had to ensure that all of the cargo on their planes was screened properly. Many combination carriers decided that this extra effort did not justify maintaining full cargo operations, and, as a result, combination carrier RTMs remained approximately constant through the 2000s[4]. Additionally, OPEX increased as a result of surging fuel prices in the late 2000s. The combination of these two factors, constant RTMs and increasing OPEX, resulted in a decreasing aggregate productivity during the 2000s, cancelling out almost all of the aggregate productivity gains realized through the 1990s.

[4] This realization provides a solid foundation to focus primarily on RTM productivity growth rather than ATM productivity, because even though the capacity (ATMs) exists the carriers do not use the full capacity. In other words, most combination carriers view cargo as a side business and focus on filling available capacity with the main business, passengers.

Aircraft Productivity

Determining the combination carrier cargo output, cargo ATMs or RTMs, per aircraft-day is a common metric of aircraft productivity. Figure 30 shows the evolution of combination carrier aircraft productivity and the trend of aircraft-days from 1990 to 2010. The aircraft productivity trends closely follow the aggregate productivity trends described above. Aircraft productivity with produced output (cargo ATMs) rose steadily until the late-2000s, when the economic recession and high fuel prices caused a reduction in cargo traffic and aircraft productivity. Cargo ATM aircraft productivity experienced a 60% increase over the past two decades. Consumed output (RTM) aircraft productivity increased almost 40% during the 1990s before experiencing steady decline through the 2000s; RTM aircraft productivity experienced a net 20% growth over the past 20 years.

As discussed above, the decline in RTM productivity during the 2000s represents the industry shift to limit cargo operations by combination carriers. It is also important to note that aircraft size and aircraft utilization strongly affect this aircraft productivity metric. This plays a key role in combination carrier analysis because of the prominent network characteristics of NLCs. NLCs tend to operate large aircraft on hub-and-spoke networks with low utilization. Operating larger aircraft would bolster productivity growth because the same amount of cargo could be carried using less aircraft-days. However, lower utilization dampens aircraft productivity growth because it may require more aircraft movements, and thus aircraft-days, to transport the same amount of cargo. While the network structure and aircraft utilization do affect aircraft productivity, ultimately, the shift of NLCs to limit cargo operations drove the decreasing RTM productivity through the past decade.

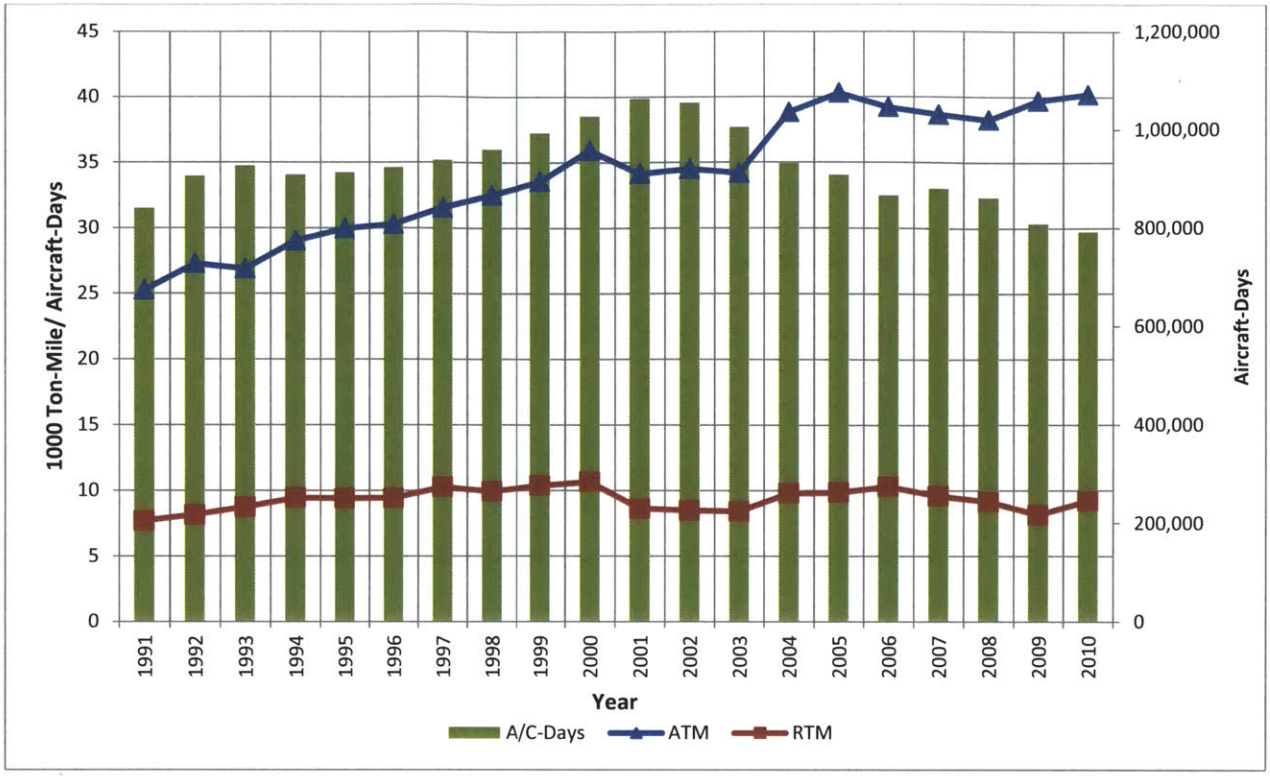

Figure 30. Combination Carrier Aircraft Productivity

Fuel Productivity

This section employs two metrics to analyze fuel productivity, a fuel consumption metric and a fuel expense metric. Figure 31 shows the trends of the fuel consumption productivity metric, as well as the evolution of total gallons of fuel consumed per year. Fuel consumption increased 40% through the 1990s, consistent with the increase in combination carrier cargo traffic at the same time. However, a significant decline in fuel consumption of nearly 50% characterizes the 2000s. The combination of decreased capacity as airlines shifted away from cargo operations and improved engine technology resulted in an overall decrease of consumed fuel. ATM fuel consumption productivity experienced steady growth during the 1990s, and even quicker growth during the 2000s. Since 1990, ATM fuel consumption productivity has increased 108%. Similarly, RTM fuel consumption productivity has increased steadily for the past 20

years, from about four ton-miles per gallon to just over six ton-miles per gallon, representing a 59% increase over 20 years.

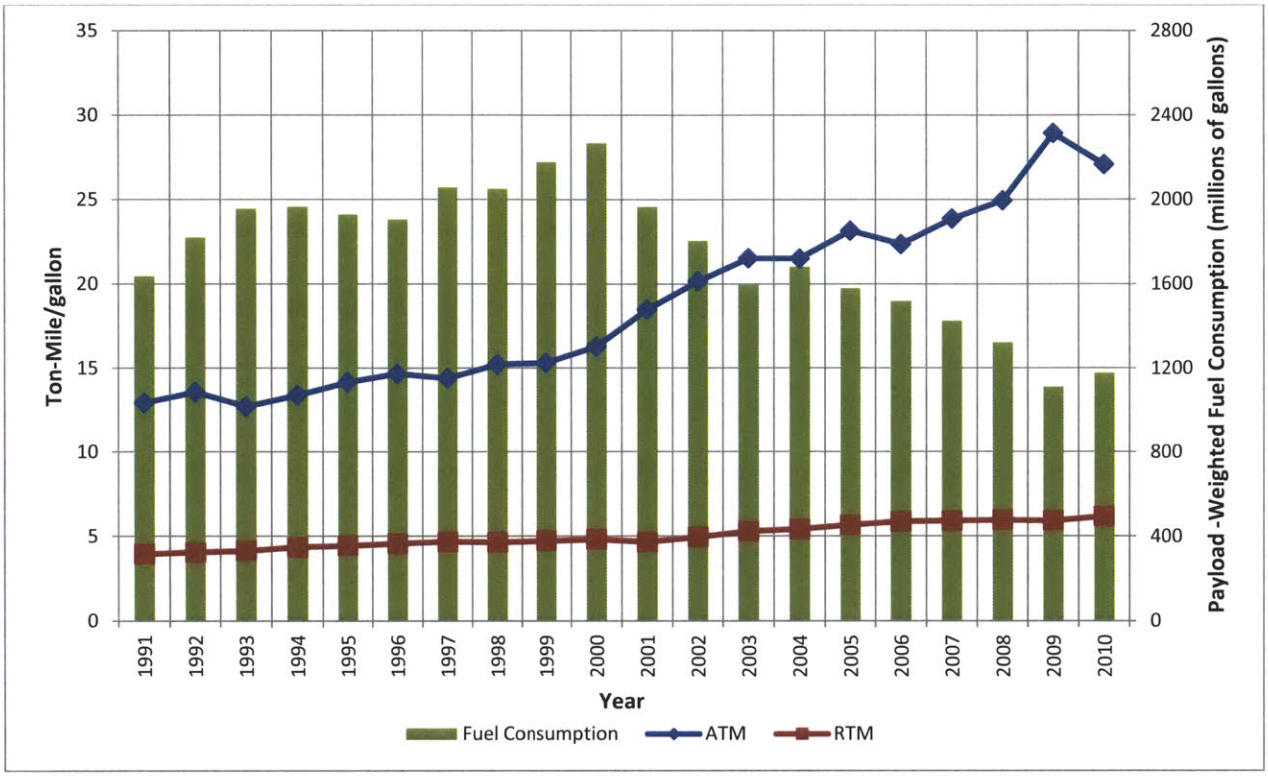

Figure 31. Combination Carrier Fuel Consumption Productivity

The productivity gains realized in the 1990s resulted from traffic growing faster than fuel consumption. However, most of the fuel consumption productivity growth occurred during the 2000s, when combination carriers made two distinct decisions to bolster productivity gains. First, they began focusing on internal efficiencies, especially as NLCs restructured through bankruptcy. As discussed in *Productivity Trends in the US Passenger Airline Industry*, improvements in capacity management, fleet scheduling and planning, and engine technologies led improved efficiencies for the airlines (Belobaba et. al, 40). Second, NLCs decreased their cargo operations, specifically eliminating their dedicated cargo flights in favor of operating only

combination flights. Consolidating operations to combination flights reduced the total number of cargo-related flights, as shown by the decreasing cargo ATMs in Section 2.4.3 US Trends: Combination Carrier Trends. Decreasing the number of cargo ATMs caused cargo-related fuel consumption to drop throughout the 2000s. The combination of these two decisions, improved efficiencies and reduced cargo capacity, drastically decreased the overall cargo-related fuel consumption realized during the 2000s. As a result, productivity gains achieved over the past 10 years resulted from decreasing fuel consumption at a faster rate than traffic growth slowed.

Fuel expense productivity is the second metric used for the fuel productivity analysis. Figure 32 shows the evolution of fuel expense productivity for cargo ATM and RTM output over the past 20 years, and the trend of fuel expense normalized to 2010 dollars during the same time span. The fuel expenses shown in Figure 15 have been weighted by the payload ratio of cargo carried by combination carriers to approximate the fuel costs directly attributable to cargo operations. Real fuel costs decreased steadily through the 1990s, just over 30% from 1990 to 1999. However, fuel prices have been extremely volatile in the 2000s, with a minor spike in 2000 and 2001, before a historically large increase peaking in 2008.

The volatility displayed in fuel costs creates volatility in the fuel expense productivity metrics. Produced (ATM) and consumed (RTM) fuel expense productivity increased from 1990 into the early 2000s, experiencing only two periods of minor decline during 1996 and 2000. Recall, however, that ATMs increased steadily during these years, indicating that increases in fuel expenses in 1996 and 2000 caused the drops in productivity. As fuel costs rose drastically through the mid-2000s, produced and consumed fuel expense productivity decreased to a trough in 2008. Productivity levels increased some in the past two years; reduced fuel costs and reduced fuel consumption produced this slight rise in productivity. ATM fuel expense

productivity has increased 23% since 1990, even though fuel prices have increased 33%, in real dollars. However, RTM fuel expense productivity experienced a minor 8.6% drop over the past two decades. Combination carriers' declining willingness to carry cargo in the past 10 years, realized in a decreasing load factor in Section 2.4.3, explains why RTM fuel expense productivity experienced a net decrease since 1990 while cargo ATM productivity experienced a net increase.

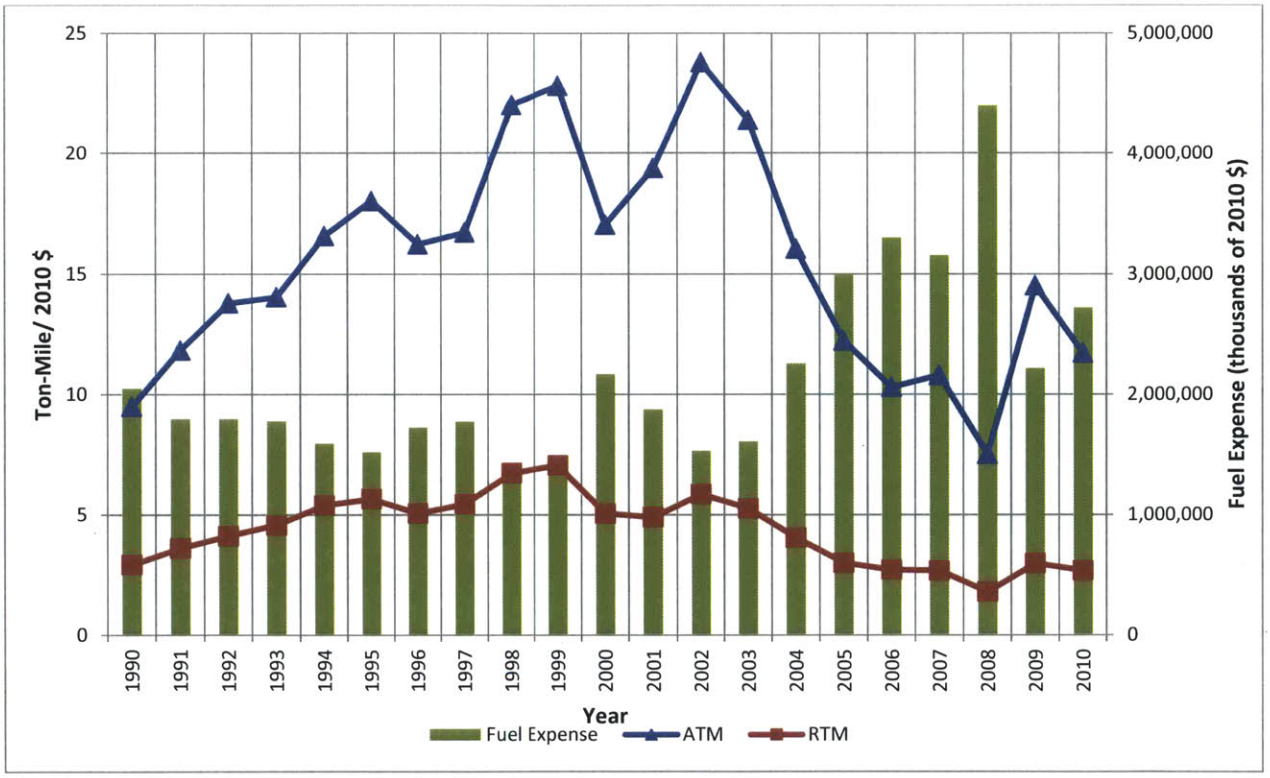

Figure 32. Combination Carrier Fuel Expense Productivity

Labor Productivity

A single metric explores labor productivity of combination carriers, defined as produced (ATM) or consumed (RTM) output per number of cargo-related full-time equivalent employees (FTEs). Figure 33 displays the trends of combination carrier labor productivity and the number

of cargo-related FTEs from 1990 to 2010. During the 1990s, cargo-related FTEs decreased from over 36,000 FTEs in 1990 to approximately 31,000 FTEs in 1996, followed by consistent growth to nearly 44,000 FTEs in 2000. Since 2000, cargo-related FTEs dropped 38% from 2001 to 2002 and have declined another 43% from 2002 to 2010. Over the past 20 years, cargo-related FTEs decreased approximately 61%.

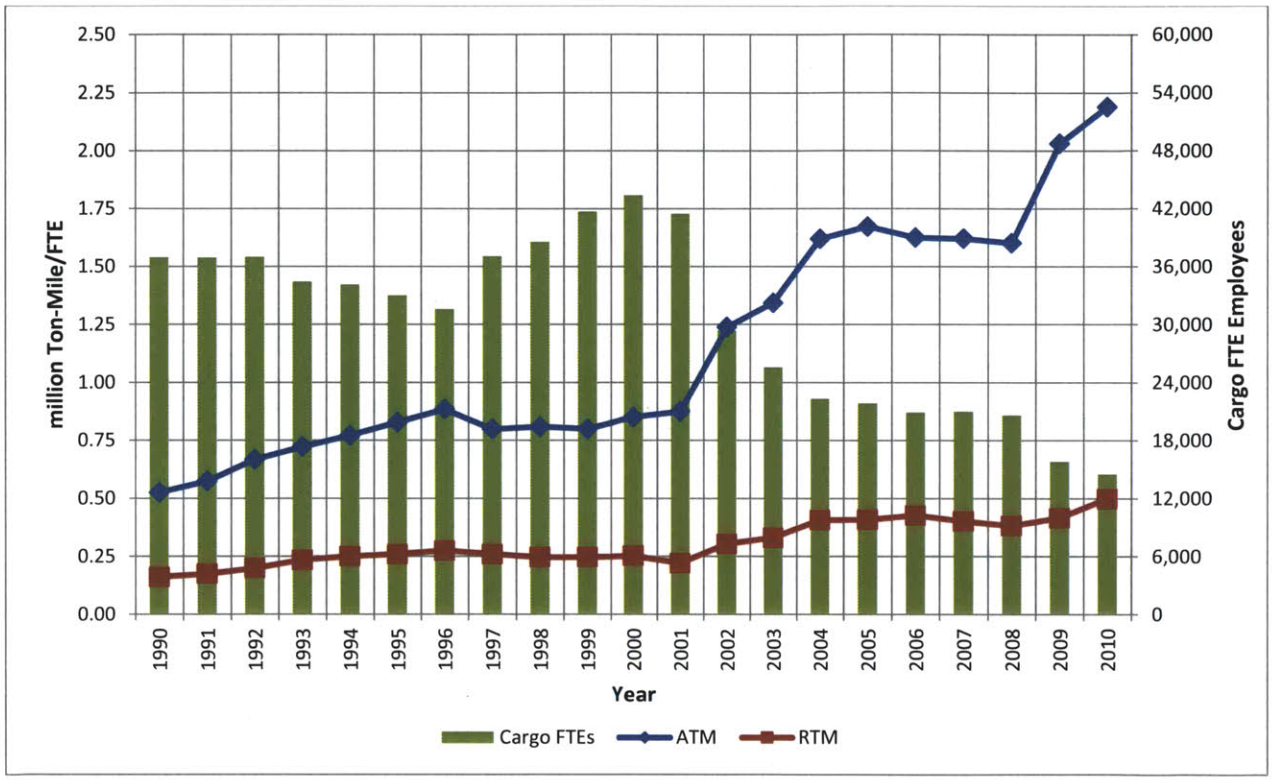

Figure 33. Combination Carrier Labor Productivity

Produced and consumed labor productivity metrics experienced similar trends during the 1990s. ATM and RTM labor productivity increased until 1996, remaining at approximately 800,000 ton-miles per FTE and 250,000 ton-miles per FTE, respectively, until 2001. Cargo-related employees decreased through the 2000s as a result of automated systems replacing human labor and the general shift of combination carriers limiting cargo-related services. The drop in cargo-related FTEs caused quick and consistent growth in ATM and RTM labor

productivity. ATM labor productivity has increased 316% since 1990, rising from approximately 530,000 ton-miles per FTE to 2,460,000 ton-miles per FTE. RTM labor productivity has increased from 160,000 ton-miles per FTE to 500,000 million ton-miles per FTE, representing a 208% growth since 1990. The industry shift away from combination carrier cargo operations, and the corresponding drop in load factor, is the main reason for RTM productivity growth lagging ATM productivity growth.

It is important to note that the apparent productivity growth experienced in the past decade may artificially be inflated. As combination carriers cut down on their cargo operations, the cargo-related employees may not have been decreased proportionally – the employees may have been reassigned to a different department, thus, an artificially small number of cargo-related employees is reported while the actual number of employees contributing to cargo operations has not changed that much. Regardless, actual productivity growth was achieved through advancements in automated services.

As discussed above for the all-cargo carriers, electronic processing of security clearance forms has reduced cargo delay times (Morrell, 154). The adoption of computerized systems has also increased labor productivity. Airlines and airports adopted systems such as the Air Cargo Community Systems (CCS) and the Global Freight Exchange (GF-X) in the early 2000s which automatically generate cargo-related documents, such as airplane load sheets, simplify cargo tracking, and accelerate file sharing between "the airport, [cargo] handlers, and customs authorities" (Morrell 187). Airlines continue to look for innovative solutions and improvements in automated services moving into the future to further improve customer service and labor productivity.

4.2 MULTI-FACTOR PRODUCTIVITY METRICS

The previous single-factor productivity analysis provided an understanding of how individual inputs affected the total output of the US air cargo industry. However, all of the inputs work together to produce a given output, ATMs or RTMs, and a multi-factor productivity (MFP) analysis provides a way to amalgamate the SFP results into one metric. This section presents the MFP results for the US air cargo industry from 1992 to 2010. All-cargo carrier MFP is discussed first, separating FedEx and UPS from the other nine carriers. The MFP results include a year-on-year growth and cumulative growth since 1992. Cumulative MFP growth includes moving input weights and constant input weights from 1992, as discussed in Chapter 3, effectively comparing the different industry strategies and how they affect MFP growth. This section wraps up by analyzing combination carrier MFP growth during the past two decades using similar year-on-year growth and cumulative growth analyses. Overall, year-on-year growth for both all-cargo carriers and combination carriers has been sporadic over the past 20 years, experiencing periods of positive and negative growth. However, the cumulative MFP analyses reveal that all-cargo carriers and combination carriers have achieved large productivity improvements since 1992.

4.2.1 All-Cargo Carriers

Year-on-year (y-o-y) and cumulative MFP results are provided in this section for FedEx/UPS and the other nine all-cargo carriers. Figure 34 shows the y-o-y MFP results for FedEx/UPS from 1992 to 2010 for ATM and RTM output. These values represent the MFP growth (increase or decrease) between two consecutive years. Positive MFP growth characterized the early 1990s, with an 8.5% increase in 1994 because of decreasing capital expenses and rebounding traffic and capacity. Following the positive growth in 1994, negative

productivity growth occurred in 1995 and 1996 as a result of increasing capital and labor expenses. Negative MFP productivity in 2000 was caused primarily by capacity decreasing. At the same time, RTM traffic expanded into the 2000s, explaining the positive MFP growth for RTMs in 2000. However, the negative RTM MFP productivity experienced in 2001 resulted from decreased traffic after the September 11th terrorist attacks. ATM MFP productivity experienced 9.1% growth in 2001 because capacity rebounded, as discussed in Section 2.4.3, while traffic, and thus fuel consumption and aircraft-days, decreased slightly.

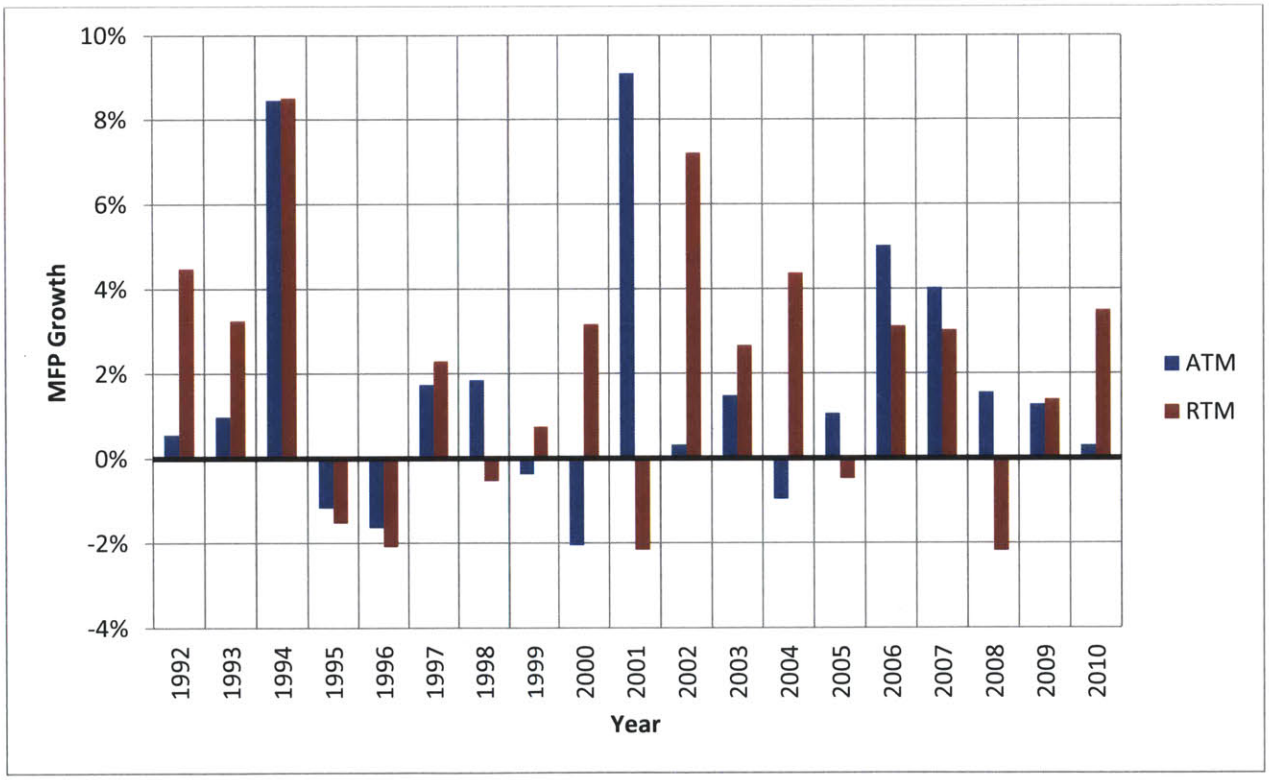

Figure 34. FedEx and UPS Year-on-Year MFP Growth

Positive MFP growth characterized the mid-2000s. This growth was fueled by increasing traffic and capacity, as discussed in Section 2.4.3. Growth slowed in the late 2000s and a two percent negative MFP growth occurred in 2008 during the economic recession as RTM traffic

decreased and fuel expenses increased. Nevertheless, 2009 and 2010 showed positive MFP growth resulting from rebounding traffic and capacity from the 2008 recession and increased labor productivity.

Figure 35 shows the cumulative MFP growth for ATM and RTM output. As discussed in Section 3.2.2, cumulative growth is reported using moving input weights, where the weights used correspond to the given year, and constant input weights from 1992. These two weighting schemes emphasize the difference between productivity in a given year based on the relative importance of inputs (labor, capital, fuel, and intermediate) in 1992 and the given year. As time progresses from 1992 to 2010, the two productivity calculations diverge with the moving input weights MFP values lower than the MFP values calculated with constant 1992 input weights. This result highlights how the increasing importance of fuel expenses and the decreasing proportion of labor cost in the past 10 years slowed productivity growth.

Based on the moving input weights, MFP productivity has grown 16.5% for RTM output and 14% for ATM output since 1992. MFP growth increased quickly in the early 1990s, with RTM productivity growing 14% and ATM productivity growing nine percent by 1994. However, rising labor costs and slowing traffic growth contributed to decreasing cumulative MFP growth during the late 1990s; from 1994 to 2000, cumulative RTM and ATM MFP growth had fallen nearly four percent, based on 1992 values.

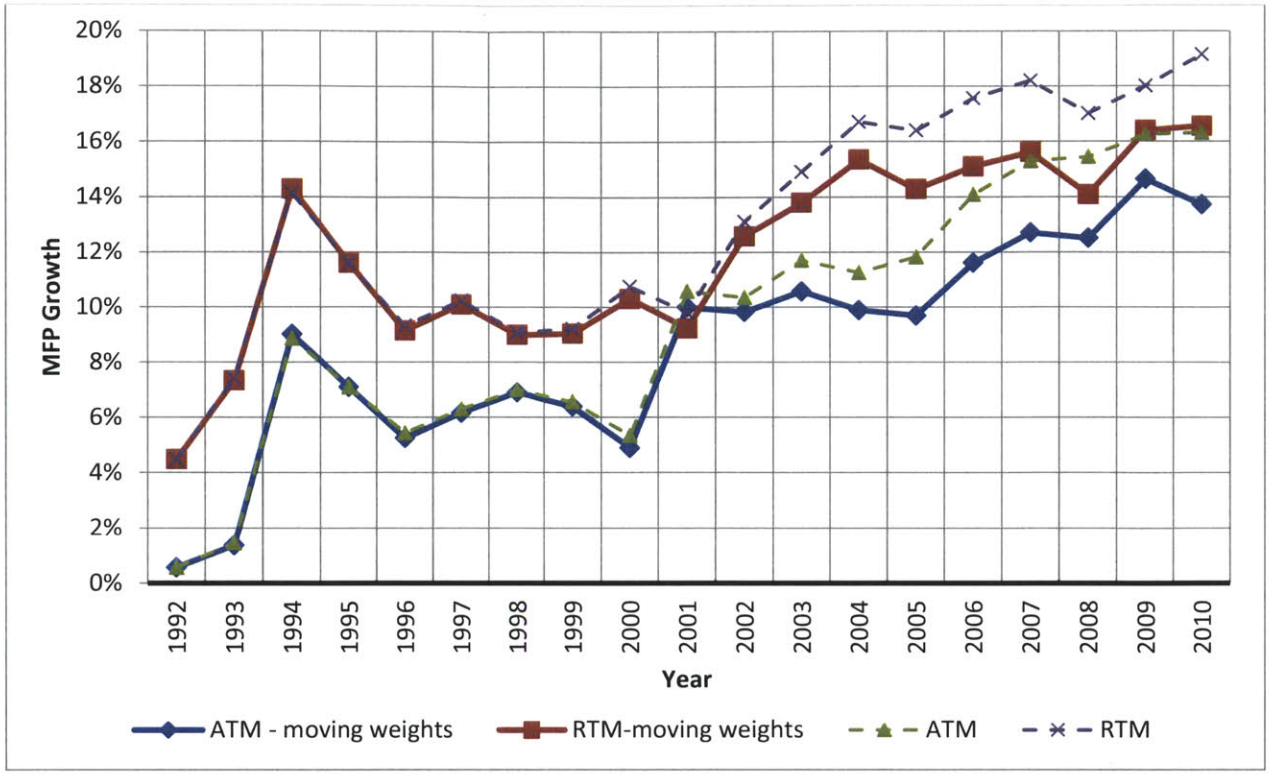

Figure 35. FedEx and UPS Cumulative MFP Growth

Strong growth emerged in the early 2000s as capacity recovered in 2001 and traffic recovered from 2002-2004. From 2000 to 2004, cumulative RTM MFP grew from around 10% to 15.5%, using 1992 as a baseline, and cumulative ATM MFP increased from approximately five percent to around 10%, based on 1992 values. MFP growth slowed over the next five years as fuel prices increased; RTM growth slowed more than ATM growth as emphasized by a decreasing load factor shown in Section 2.4.3. Cumulative RTM MFP grew one percent from 15.5% in 2004 to 16.5% in 2010, based on 1992 values, while cumulative ATM MFP grew from 10% to 14% during the same time span, using 1992 as a baseline.

Year-on-year MFP growth for the other all-cargo carriers experienced a mixed record of positive and negative MFP growth, similar to y-o-y productivity growth exhibited by FedEx/UPS. However, recall from Sections 2.4.3 and 4.1.1., the entry and exit of prominent all-cargo carriers affected data and gave the illusion of productivity improvements in certain years. This affect appears in the MFP results, and gray regions identify the questionable MFP results caused by these data.

Figure 36 presents the y-o-y MFP results for the all-cargo carriers from 1992 to 2010 for ATM and RTM output. The 1990s began with positive MFP growth during 1992 and 1993 resulting from growing traffic figures out of the 1990 mini-recession, as described in Section 2.4.3. Y-o-y MFP growth decreased nearly 20% during 1997 and 1999 when labor productivity declined because of decreasing RTMs and ATMs while FTEs continued to grow, as discussed above in Section 4.1.1. Positive growth occurred from 2000 to 2003 following the negative growth in the late 1990s, with y-o-y RTM MFP growth peaking at 38% in 2000 and y-o-y ATM MFP growth peaking at 37% in 2002. Parts of this growth resulted from strong ATM and RTM growth in the early 2000s, as discussed in Section 2.4.3. However, recall that Emery Worldwide Airlines exited the industry in 2001. The data show that total all-cargo ATMs and RTMs did not decrease proportionally with labor, fuel, and capital inputs in the early 2000s, corresponding with Emery's exit. This situation results in an apparent increase in productivity, but these results are questionable because of the suspicious data reported.

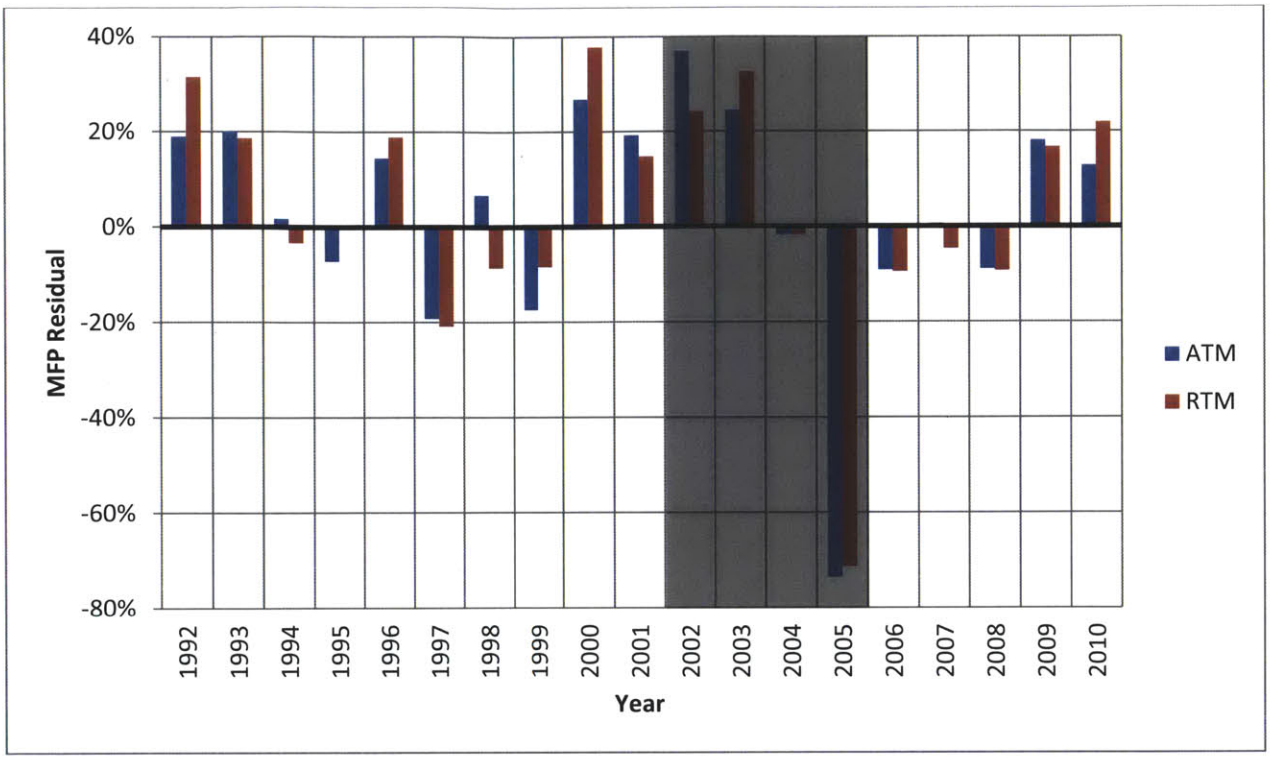

Figure 36. All-Cargo Carrier Year-on-Year MFP Growth

Similar data reporting issues raise questions about the 70% negative y-o-y MFP growth shown in 2005. ABX Air entered the air cargo industry in 2003 and began growing rapidly in 2005. When their growth occurred in 2005, they reported increases in labor, capital, and fuel inputs while total ATMs and RTMs remained approximately constant. This is the root cause of the apparent 70% decrease in all-cargo carrier productivity in 2005. A gray box surrounds these data in Figure 36 to signify the questionable nature of these results.

Following 2005, negative y-o-y MFP values around -10% occurred from 2006 to 2008 This negative growth resulted from decreasing ATMs and RTMs and increasing fuel prices during that time period leading into the 2008 economic recession, as discussed in Section 2.4.3. However, y-o-y MFP for all-cargo carriers grew almost 20% in 2009 and 2010, indicating positive growth out of the economic recession. Increasing ATMs and RTMs drove this growth

with further support from increased labor and capital productivity, as discussed above in Section 4.1.1.

The growth of the all-cargo carriers in the early 1990s and the early 2000s resulted in large cumulative MFP growth. Figure 37 shows the all-cargo carrier cumulative MFP growth from 1992 to 2010. As discussed above, data shown include moving input weights and constant input weights from 1992 to provide a comparison between productivity in a given year based on the relative importance of input values in the given year and the relative importance of input values in 1992.

In the first half of the 1990s, all-cargo carriers realized 190% growth in RTM cumulative MFP and around 140% growth in ATM cumulative MFP, based on the moving input weights. However, when labor productivity decreased in the late 1990s, along with decreasing traffic figures, RTM cumulative MFP dropped 60% to 130% in 1999 and ATM cumulative MFP dropped to around 100% in 1999. The significant y-o-y MFP growth realized from 2000 to 2003 resulted in extreme cumulative MFP growth as input values decreased while ATMs and RTMs increased. However, recall from the all-cargo carrier y-o-y MFP discussion that this apparent productivity growth is questionable because of uncertainty in data reported for input quantities from 2002 to 2005.

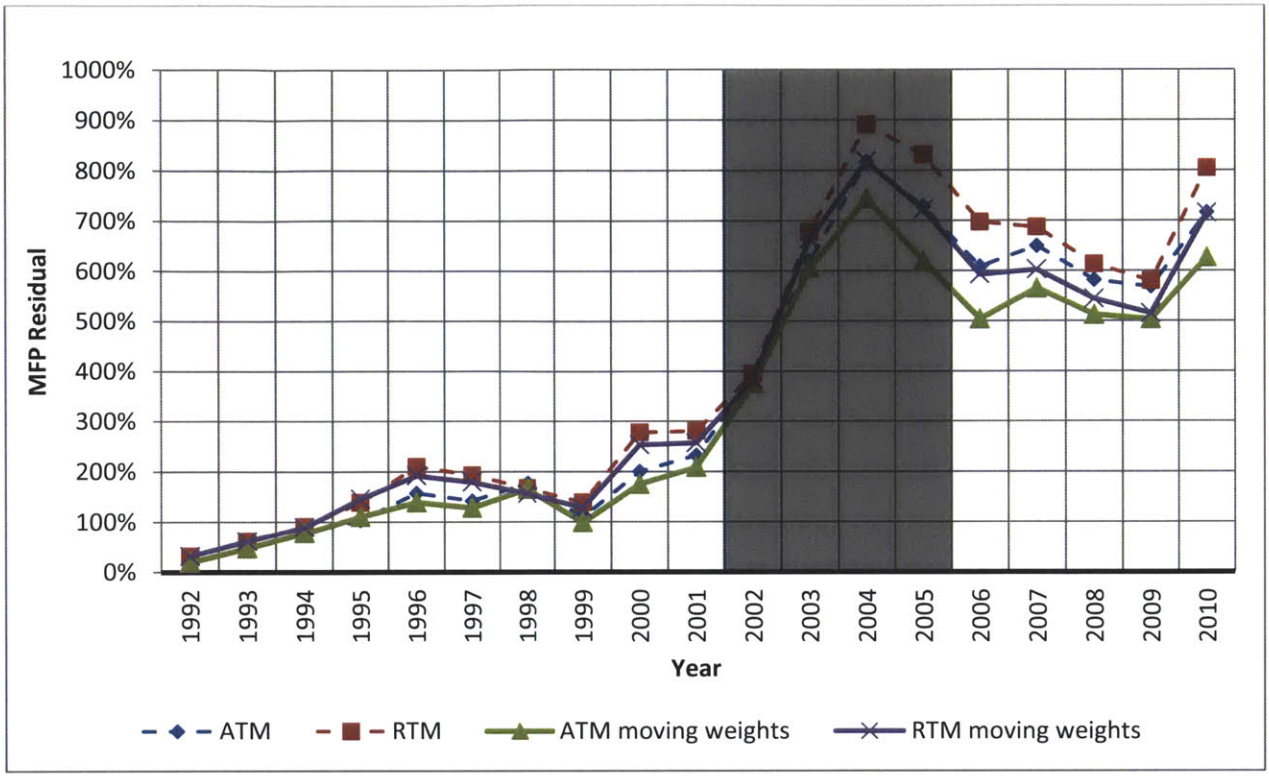

Figure 37. All-Cargo Carrier Cumulative MFP Growth

The all-cargo carriers experienced negative cumulative MFP growth throughout the mid-2000s resulting from increasing input values as ABX Air expanded, as discussed above. The positive growth experienced from 2009 to 2010 resulted from traffic growth out of the 2008 recession and helped recover and boost cumulative MFP growth. From 1992 to 2010, cumulative MFP for all-cargo carriers appears to have grown 715% for RTM output and 630% for ATM output. However, these cumulative MFP values we calculated include questionable data from 2002 to 2005, and therefore, these results may not reflect the actual industry growth during that time.

It is interesting to note that the two cumulative MFP calculations, with moving input weights and constant 1992 input weights, diverged as time progressed from 1992 to 2010. In 2010, cumulative MFP values calculated using constant 1992 input weights were approximately 100 percentage points more for both ATM and RTM output. This emphasizes the evolution of the air cargo industry over the past 20 years. Notably, an increasing importance of fuel costs and a decreasing proportion of labor costs throughout the past decade have slowed productivity growth.

Additionally, we want to emphasize the limitations on the other all-cargo carrier MFP results shown above. The entry and exit of several carriers in the early 1990s and the early 2000s caused questionable spikes in the data, as discussed in Section 3.4.2. Acknowledging these questionable data, we proceeded naively with productivity calculations. The figures shown above for the other all-cargo carriers reflect the questionable data and provide productivity values using the questionable data.

4.2.2 Combination Carriers

MFP results are presented for combination carriers in this section, including year-on-year and cumulative MFP, as discussed in Section 3.2.2. Year-on-year (y-o-y) MFP growth for combination carriers presents a mix of positive and negative values. The positive growth corresponds to periods of prosperous growth and productivity improvements, such as the early 1990s and the early 2000s, and the negative growth corresponds to recessionary periods and major events that affected the combination carrier industry, such as the September 11th terrorist attacks and the economic recession in the late 2000s. Figure 38 shows the y-o-y MFP growth for combination carriers from 1992 to 2010 for ATM and RTM output.

In the early 1990s, y-o-y MFP grew between five percent and 10% per year until 1996. This growth resulted from increasing ATMs and RTMs through the early 1990s out of the 1990 mini-recession. However, y-o-y MFP growth slowed in the late 1990s as the number of NLC cargo-handling employees increased, decreasing combination carrier labor productivity. A 17% negative MFP growth occurred for RTM output in 2001 as a result of the September 11th terrorist attacks, which drastically reduced RTM traffic that year.

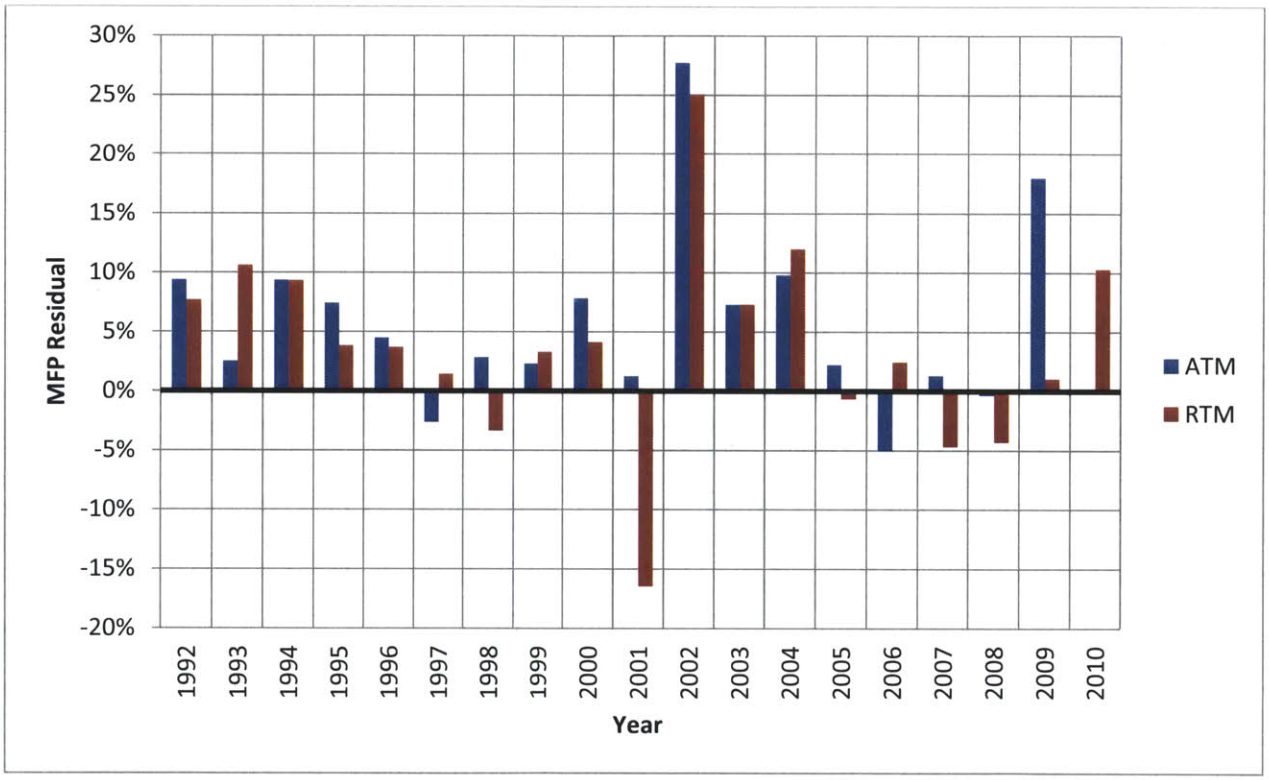

Figure 38. Combination Carrier Year-on-Year MFP Growth

After 2001, combination carriers achieved positive y-o-y MFP growth in the early 2000s. MFP productivity increased around 25% in 2002, followed by 7% and 10% in 2003 and 2004, respectively. This y-o-y MFP growth resulted from several large NLCs increasing labor productivity by reducing labor expenses during bankruptcy restructuring negotiations in the early

2000s; restructured labor contracts deemphasized labor inputs for the productivity calculation which led to improved labor productivity. Additionally, traffic and capacity began to rebound from the low figures in the early 2000s, as discussed in Section 2.4.3.

Growth slowed by 2005, and negative y-o-y MFP productivity occurred from 2006 to 2008. In 2006, ATM y-o-y MFP decreased 5%, followed by approximately 5% decreases in RTM y-o-y MFP in 2007 and 2008. Declining y-o-y MFP in the late 2000s resulted from decreasing capacity and traffic as combination carriers began limiting cargo operations, as discussed in Sections 2.3.1 and 2.4.3. The 2000s ended with an 18% ATM y-o-y MFP growth in 2009 and a 10% RTM y-o-y MFP growth in 2010. Labor decreases influenced both of these MFP increases, as well as RTM growth out of the 2008-2009 economic recession, specifically bolstering the 2010 RTM y-o-y MFP growth.

The strong y-o-y MFP growth in the early 1990s and early 2000s helped the combination carrier cargo industry realize strong cumulative MFP growth over the past two decades. Figure 39 shows the cumulative MFP growth for combination carriers from 1992 to 2010, with moving input weights and constant input weights from 1992. Combination carrier cumulative ATM and RTM MFP grew 33% and 31%, respectively, from 1992 to 1996. As labor productivity decreased in the late 1990s, as described in Section 4.1.2, cumulative MFP growth stalled hovering around 30% until the early 2000s.

RTM cumulative MFP decreased 10% in 2001 to 22% as a result of the decrease in RTMs following the September 11th terrorist attacks. However, as labor productivity increased in the subsequent years, ATM cumulative MFP increased to 79% in 2004 and RTM cumulative MFP increased to 66% in 2004. Cumulative MFP growth stalled around these values in the mid-

2000s as combination carrier cargo operations decreased. Reduced cargo operations resulted in ATM cumulative MFP decreasing to 72% in 2008, and RTM cumulative MFP dropping to 54% in 2008 at the bottom of the economic recession. As discussed above, labor productivity increased in 2009 and 2010, along with RTMs increasing in 2010. These events contributed to the surge in our calculations of cumulative MFP growth realized during 2009 and 2010 for combination carriers. Since 1992, ATM cumulative MFP increased 108% and RTM cumulative MFP increased 86%.

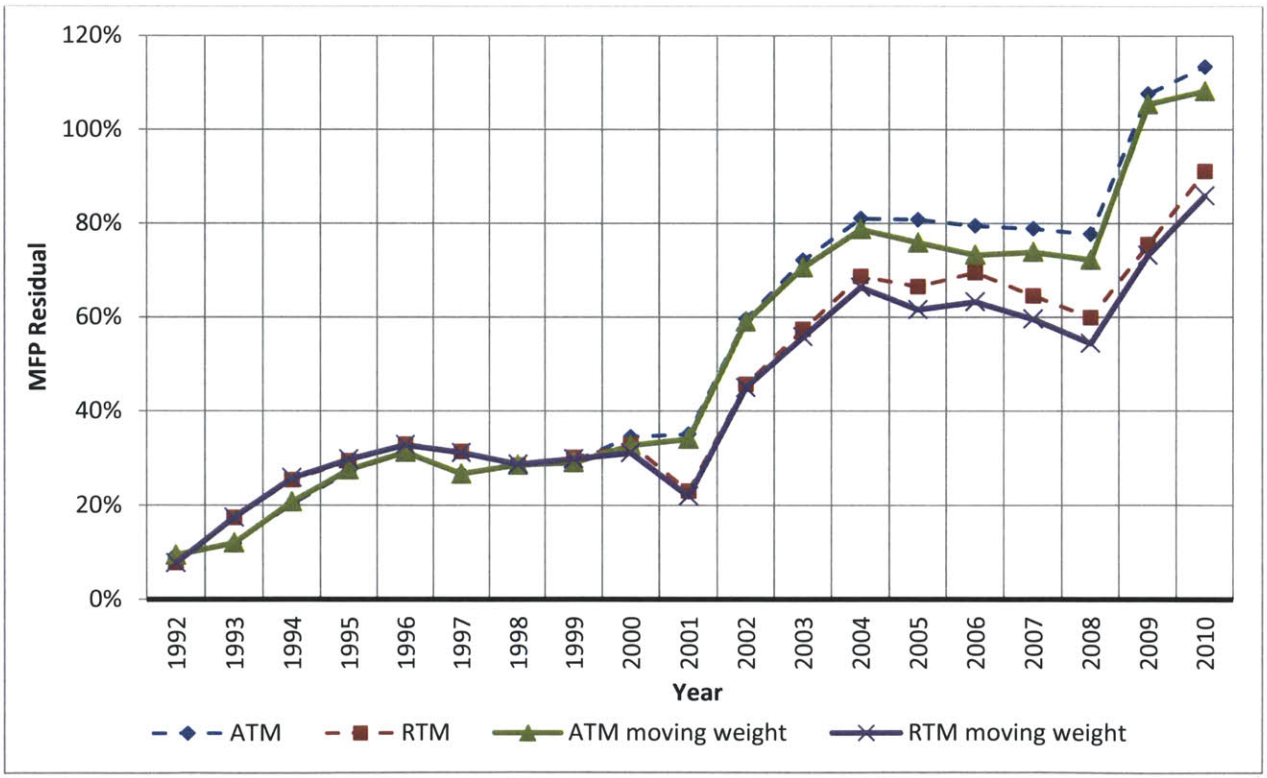

Figure 39. Combination Carrier Cumulative MFP Growth

Similar to the all-cargo carriers above, divergence between the moving input weights MFP values and the constant 1992 input weights MFP values occurred during the mid-2000s. Rising fuel prices emphasized fuel consumption in the MFP calculation, causing divergence between the two MFP values. However, as combination carriers limited their cargo operations toward the end of the decade, the emphasis of fuel consumption decreased, productivity growth appeared to accelerate, and the two MFP values converged again.

Measuring cargo-related productivity for combination carriers caused difficulties and forced limitations on the results shown above. Recall from Chapter 3, the data from BTS Form 41 is not specific enough to allocate accurately only cargo-related inputs for combination carriers. Methods were used to approximate the cargo-related data, as described in Chapter 3, but this inherently limits the accuracy of the results shown above. One solution to this issue would be working with several combination carriers to obtain detailed data, but this would require a lot of time and generous cooperation from airlines.

4.3 CHAPTER SUMMARY

This chapter presented the productivity results calculated using the data and methodology described previously in Chapter 3. Four different single-factor productivity (SFP) metrics were analyzed in this chapter: aggregate productivity, aircraft productivity, fuel productivity, and labor productivity. The multi-factor productivity (MFP) metric examined in this chapter included a year-on-year growth analysis and a cumulative growth analysis, dating back to 1992. For all productivity analyses, RTM and ATM quantities are used as outputs.

Regarding SFP results, FedEx and UPS realized almost no net change in aggregate productivity over the past 20 years. However, they realized gains for aircraft, labor, and fuel consumption productivity, separately. The greatest improvements were achieved in labor productivity because of wide-spread adoption of computerized and automated services. Newer aircraft and improved load management also lead to fuel consumption productivity improvements. MFP showed steady positive growth since 1992, with the exception of a few years in the late 1990s and late 2000s caused by labor and capital cost growths and economic recessions, as discussed in Section 2.4.3.

The other all-cargo carriers showed great improvements in SFP over the past two decades. However, data movements associated with the entry and exit of all-cargo carriers affected the productivity metrics and caused questionable results. Acknowledging these limitations, we proceeded to calculate productivity values. Our calculations show that all-cargo carriers nearly doubled aggregate productivity over the past 20 years. Other significant improvements appeared for aircraft productivity and labor productivity. MFP growth appeared volatile since 1992, when calculated with the questionable data. The early 1990s and the early 2000s showed strong MFP growth, yet negative growth characterized the late 2000s.

Combination carriers achieved moderate productivity growth since 1990 despite limiting cargo operations in the mid-2000s, as discussed in Section 2.4.3. For SFP growth, aggregate and aircraft productivity showed almost no net change, but fuel consumption and labor productivity revealed consistent growth over the past 20 years. This growth was achieved through improved capacity management, fleet scheduling, introducing newer aircraft, and implementing computerized services. MFP growth nearly doubled over the past 20 years, experiencing the most change in the early 1990s and the early 2000s, during prosperous periods, as mentioned in Section 2.4.3. Additionally, recessionary periods in the late 1990s and late 2000s, the September 11th terrorist attacks, and reduced cargo operations in the late 2000s all contributed to slowing MFP growth over the past 20 years.

5. CONCLUSIONS

The US air cargo industry has grown significantly in the past 30 years, evolving and responding to internal and external changes. Major US airlines have experienced events such as industry deregulation, periods of war, multiple economic recessions, terrorist attacks, and historic increases in fuel prices. This thesis examined how these events have shaped the US air cargo industry. Furthermore, this thesis focused on the evolution of productivity metrics for US cargo airlines over the past 20 years.

Deregulation of the airline and trucking industries in the late 1970s and early 1980s triggered the emergence and growth of cargo airlines and the US air cargo industry. Two broad categories of cargo airlines exist, combination carriers and all-cargo carriers. Airlines that participate in both the passenger and cargo industries are classified as combination carriers, and those airlines that exclusively operate in the cargo industry are all-cargo carriers. This thesis further separates all-cargo carriers into vertically integrated freight companies, which perform all aspects of freight shipping – air transport, freight forwarding, and trucking – and other all-cargo carriers, who charter cargo space on their aircraft. The combination carriers analyzed in this thesis consist of: American Airlines, Alaska Airlines, Continental Air Lines, Delta Air Lines, Hawaiian Airlines, Northwest Airlines, and United Airlines. The all-cargo carriers analyzed include: Centurion Cargo, Emery Worldwide Airlines, Atlas Air Inc., Polar Air Cargo, Air Transport International, Southern Air Inc., ABX Air, Evergreen International Inc., and Kalitta Air, and the integrated freight companies comprise FedEx and UPS.

We extracted data from the US Bureau of Transportation Statistics (BTS) Form 41 to use within this thesis. US airlines report operating data to BTS Form 41, which is made publicly available online. BTS Form 41 contains an array of data including financial operating balance

sheets, traffic and capacity reports, and employee statistics. Combination carrier data were modified, as discussed in Chapter 3, to separate out only the cargo-related data. Data remained unmodified for the all-cargo carriers.

5.1 US AIR CARGO INDUSTRY: TRAFFIC AND COSTS

FedEx and UPS showed the most consistent trends during the past 30 years, in terms of traffic and capacity. Capacity (ATMs) outgrew traffic (RTMs), for FedEx and UPS, through the late 1980s and into the 1990s. As a result, load factor steadily declined from 66% in 1987 to approximately 56% in 1991. However, traffic growth picked in through the 1990s, growing at approximately 10% per year, while ATMs grew at approximately 8.5% per year. This resulted in an increasing load factor, which peaked near 62% in 2000. The September 11th terrorist attacks caused a quick drop in traffic in 2001, but RTMs rebounded the following year and began growing faster than ATMs until 2004. The latter half of the 2000s saw ATM growth outpace RTM growth, and a decreasing load factor, as the US economic receded 2008. However, similar to earlier crises, traffic rebounded following the recession and load factor increased in 2010.

Operating expenses (OPEX) for FedEx and UPS grew in a similar fashion to the traffic growth over the past 20 years. From 1990 to 2010, OPEX grew from $6.5 billion to $19 billion dollars. However, unit costs, OPEX per ATM, remained relatively constant near 60 cents per ATM for the past 20 years because OPEX and capacity grew at similar rates. Nevertheless, noteworthy changes in OPEX occurred, specifically regarding the proportions of the four OPEX categories: labor, capital, fuel, and intermediate. As fuel prices increased in the past decade, the fuel proportion of OPEX increased from 17% to 23% while labor and capital proportions decreased three percent and seven percent, respectively.

The other all-cargo carriers experienced the largest growths over the past 30 years; however the entry and exit of several carriers over the past 20 years affected much of the growth and caused significant movement in the reported data. The other all-cargo carrier traffic grew over 300% from 1983 to 1989 before a minor decrease in traffic during the 1990 mini-recession in the US. However, growth resumed the following year, and continued into the late 1990s. By 1997, ATMs had grown almost 350% and RTMs grew nearly 400% since 1990, causing corresponding growth in load factor. Growth stalled around the turn of the century until after the terrorist attacks in 2001. The entry of Kalitta Air and ABX Air into the industry and the sudden increase in traffic for Atlas Air caused the substantial growth through the early 2000s. Beginning in 2006, load factor decreased leading into the 2008 economic recession, and bottomed out at 58% in 2009. However, traffic growth in 2010 bolstered load factor to nearly 62%, showing growth at the end of the decade.

Other all-cargo carriers' OPEX increased over the past twenty years, following similar growth patterns realized in ATM and RTM growth. From 1990 to 2010, OPEX grew from $600 million to around $3.75 billion, with major increases corresponding with traffic growths in the early 1990s and the early 2000s. However, unlike the steady nature of unit costs for FedEx and UPS, the other all-cargo carriers achieved great reductions in unit costs during the past 20 years. Since 1990, unit costs have nearly halved, decreasing from around 50 cents per ATM to nearly 25 cents per ATM, as a result of increasing system-wide capacity with larger planes and longer stage flights. The increased system capacity spreads fixed costs over more capacity and drives down unit costs. As with FedEx and UPS, the proportions of different OPEX categories have changed over the past two decades. Fuel expenses have increased dramatically as a percentage

of OPEX, increasing from 17% in 1990 to 36% in 2010. On the other hand, labor costs decreased from 28% to 19% of OPEX during the past 20 years.

The evolution of combination carrier traffic differed from all-cargo carrier traffic in the past three decades. Combination carrier ATMs doubled from 1983 to 1990 and RTM traffic increased nearly 70% during the same time. Similar growth continued through the 1990s, with ATMs continuing to grow over seven percent per year and RTMs around five percent per year. This resulted in load factor steadily declining from around 38% in the early 1980s to 30% in 2000. Following the terrorist attacks in 2001, both RTMs and ATMs began decreasing, which lasted through the rest of the decade. As of 2010, load factor had decreased to around 22%. The primary reason for the decline of traffic within the past decade is the increase in security regulations imposed on airlines carrying cargo on passenger flights after the September 11th terrorist attacks.

With the slow growth of cargo traffic in the 1990s and the declining traffic growth during the 2000s, combination carriers also realized decreasing cargo-related operating expenses and unit costs over the past 20 years. While some cost reductions occurred through decreases in intermediate expenses, most of the cargo-related OPEX decreases occurred because of combination carriers limiting their cargo operations. The decreased cargo operations reduced total cargo-related fuel costs. Additionally, labor costs decreased as NLCs restructured labor contracts during bankruptcy negotiations in the early and mid-2000s. Like the all-cargo carriers, however, fuel costs as a percentage of cargo-related OPEX increased significantly through the past decade, reaching 33% in 2010, while labor and capital cost proportions decreased three percent and eight percent, respectively.

5.2 US AIR CARGO INDUSTRY PRODUCTIVITY

Single-Factor Productivity

Four different single-factor productivity metrics were analyzed in this thesis: aggregate productivity, aircraft productivity, fuel productivity, and labor productivity. For FedEx and UPS, aggregate productivity measures, output per OPEX, show almost no change in productivity over the past 20 years for both ATM and RTM output. Additionally, aircraft utilization remained constant just above 3.5 hours per day for the last two decades. However, FedEx and UPS realized gains for aircraft, labor, and fuel consumption productivity, separately. For aircraft productivity, ton-miles per aircraft-day, FedEx and UPS improved 70% for ATM output and 87% for RTM output. Slightly smaller improvements occurred for fuel consumption productivity, ton-miles per gallon of fuel consumed; ATM fuel consumption productivity increased 25% since 1991 and RTM fuel consumption productivity increased 35% since 1991. These metrics were improved by introducing new and larger aircraft into the fleet over the past two decades, improving fuel efficiency with new engines, and with improvements in load factor, carrying more cargo on each flight. Lastly, labor productivity improved 80% and 88% for ATM and RTM output, respectively, because of wide-spread adoption of computerized and automated services for cargo load management and reservations.

The other all-cargo carriers experienced significant improvements for each of the single-factor productivity metrics analyzed in this thesis. However, many of the metrics were affected by data movements associated with the entry and exit of several carriers throughout the past 20 years, and some of the reported data appears questionable. We proceeded to calculate productivity values, acknowledging the limitations of the questionable data. Aggregate productivity appeared to grow 85% for ATM output and 102% for RTM output since 1990.

Aircraft productivity and labor productivity exhibited cyclical trends with large peaks in the early 2000s. Net growth was achieved for these two productivity metrics through introducing larger aircraft with longer stage lengths and through implementing computerized and automated services. Fuel consumption productivity showed consistent growth throughout the past 20 years, unlike the cyclical trends realized in other metrics. Newer aircraft and improvements in load factor contributed to this consistent growth by improving fuel efficiency and carrying more cargo per flight.

Combination carriers achieved productivity improvements similar to the other all-cargo carriers throughout the past 20 years. However, most productivity growth occurred with capacity (ATM) output rather than traffic (RTM) output because combination carriers have limited cargo operations in the past decade. Therefore, the RTM productivity metrics provide a better indication of cargo-related productivity changes for combination carriers. Aggregate productivity and aircraft productivity have experienced almost no net change over the past two decades after growing during the 1990s and decreasing in the 2000s. Conversely, fuel consumption and labor productivity experienced consistent growth since 1990. RTM fuel consumption productivity grew 59% since 1991 as combination carriers improved capacity management, fleet scheduling and planning, and introduced newer, more fuel-efficient aircraft into their fleets. Lastly, RTM labor productivity increased 208% from 1990 to 2010, reflecting the major improvements airlines made by implementing computerized services.

Multi-Factor Productivity

The multi-factor productivity (MFP) metric examined in this thesis included a year-on-year (y-o-y) growth analysis and a cumulative growth analysis, dating back to 1992, for ATM

and RTM output quantities. FedEx and UPS showed some positive y-o-y MFP growth in the early 1990s, but increasing capital and labor expenses in the mid and late 1990s caused small or negative MFP growths. The September 11th terrorist attacks caused a noticeable drop in RTM MFP in 2001, but positive MFP growth ensued the following year; increasing traffic and capacity fueled this growth until the late 2000s. MFP growth slowed to less than 2% per year during the 2008 economic recession, but rebounding traffic figures in 2010 provided positive growth at the end of the decade. Cumulative MFP growth developed consistently with the y-o-y MFP trends. Steep growth occurred in the early 1990s, but cumulative growth stalled in the second half of the 1990s. Growth resumed in the 2000s and steadily grew until 2010. Since 1992, FedEx and UPS realized 15.5% increase in RTM MFP and a 14% increase in ATM MFP.

Year-on-year MFP growth for the other all-cargo carriers exhibited a cyclical trend over the past twenty years, similar to the trends realized in single-factor productivity metrics. It is important to reiterate that the data for the other all-cargo carriers is questionable because of the entry and exit of several carriers since 1990. Regardless, we proceeded naively to calculate productivity metrics with this data; we highlighted the questionable results appearing throughout this thesis, which occur mostly between 2002 and 2005. Positive y-o-y MFP growth occurred in the early 1990s as all-cargo carrier traffic grew. However, the second half of the 1990s showed negative y-o-y MFP growth because of increasing labor expenses and decreasing labor productivity. Increasing traffic and capacity caused positive y-o-y MFP growth in the early 2000s. Negative y-o-y MFP growth characterized the mid-2000s because of sudden increases in labor, capital, and fuel inputs. Nevertheless, the 2000s ended with positive y-o-y MFP growth because of rebounding traffic. Cumulative growth grew rapidly in the early 1990s, but the

negative y-o-y MFP growth in the late 1990s stalled cumulative growth. Similarly, cumulative MFP increased dramatically in the early 2000s, but decreased for second half of the decade.

Combination carrier MFP growth had similar characteristics to the other all-cargo carriers. Year-on-year MFP showed positive growth in the early 1990s, but MFP growth waned in the late 1990s as labor and capital costs increased. The September 11th terrorist attacks caused a large negative y-o-y RTM MFP growth. Nevertheless, MFP growth resumed the following year and continued into the mid-2000s as NLCs reduced labor expenses during bankruptcy restructuring. MFP growth slowed in the second half of the 2000s as combination carriers began limiting their cargo operations. Combination carriers experienced nearly 100% cumulative MFP growth over the past two decades, fueled mostly by growth in the early 1990s and early 2000s. Additionally, a surge of labor productivity and RTM traffic in 2009-2010, helped bolster cumulative MFP in the late 2000s.

Beyond these results, several limitations and difficulties in calculating productivity metrics must be emphasized. Foremost, inconsistent and questionable data reporting by all-cargo carriers caused periods of questionable results from 2002 to 2005 and prevented robust productivity calculations. Additionally, distinguishing only cargo-related data for combination carriers proved difficult using publicly available data from the BTS Form 41, specifically regarding input and output quantities such as fuel consumption, labor statistics, and capacity measurements. Methods were used to approximate the cargo-related data, as described in Chapter 3, but the approximations limit the accuracy of the calculations provided within this thesis. Lastly, it is important to note the limitations in the productivity metrics. This thesis analyzed only three specific inputs: fuel, labor, and capital, and a fourth category, intermediate, serving as a catch-all input. These are very broad categories of inputs which could be segmented

into more detailed input groups to provide increased accuracy for productivity results. For example, within labor inputs, automated services and reservation systems could be separated from cargo-handling employees. However, it is very difficult to determine input quantities to represent these detailed inputs, and, therefore, this thesis focused on the broad input categories.

5.3 FUTURE RESEARCH

There is plenty of opportunity to expand this research moving forward that would provide better insight into air cargo productivity. First, a regression analysis could be performed to analyze how different variables affect productivity. For example, factors such as economic recessions, airline bankruptcies, and wars have affected air freight productivity over the past 20 years. A regression analysis of such factors would help explain the extent that each factor contributed to changing air freight productivity.

Second, more detailed analyses of individual air freight carriers could be pursued. Collaboration with individual carriers would facilitate accurate data and eliminate many of the unresolved questions about data in this thesis. Additionally, collaborating with a combination carrier would provide better insight into separating cargo-related data from the aggregate data.

Third, recall that this thesis used simple productivity metrics analyzing four broad inputs, including a catch-all category, and two outputs. Future research could focus on developing more in-depth measures of productivity that better describe and measure the complex operations of air cargo operators. A major difficulty in this research would be quantifying detailed productivity inputs. However, this might be resolved through working with industry experts and airlines.

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