Productivity Performance of US Passenger Airlines since Deregulation

by

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Abstract

To evaluate US passenger airlines’ productivity performance since the airline deregulation in 1978, this research measures and compares productivity at both the US airline industry and individual carrier levels.

Productivity is measured at the aggregate airline industry level in terms of multifactor productivity (MFP), the ratio of a single output to a combination of inputs, in order to compare industry productivity over time from 1978 to 2009. In addition, productivity is measured at the disaggregate carrier level in terms of total factor productivity (TFP), the ratio of total outputs to total inputs, to compare productivity growth across airlines and over time from 1995 to 2010.

Our key findings indicate US passenger airlines have experienced tremendous MFP improvements since deregulation despite periods of reduced productivity levels that coincide with exogenous factors that include economic recessions, fuel price spikes, and other unforeseen events. Cumulative MFP in terms of airline traffic (RPMs) and network capacity (ASMs) increased 191% and 117%, respectively, between 1978 and 2009. This implies, irrespective of output measure, US passenger airlines have at least doubled their productive abilities over the past three decades. If RPMs are used as the measure of output, productivity has almost tripled.

Looking at individual US carriers’ productivity, low-cost carriers achieved rapid TFP growth in the early 2000s before leveling off in the latter portion of the decade. The restructuring efforts of legacy carriers enabled them to improve their productivity growth in the latter part of the 2000s, although at a much lower rate than their low-cost counterparts. As of 2010, although low-cost carriers had a slight advantage in TFP levels, evidence of convergence exists, irrespective of carrier type. Regression analyses indicates, on average, low-cost carriers experienced higher TFP growth and network control variables such as average stage length, load factor, and block hours per day were important factors that help explain observed TFP differentials among carriers.

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Title: Principal Research Scientist of Aeronautics and Astronautics
Acknowledgments

Just two years ago, I arrived at MIT confident that my research interests involved public transportation, but when I heard about this project looking at the productivity of various modes of transportation, particularly the airline industry, I immediately jumped to the opportunity. Since then, I have immersed myself in past literature and coursework to learn about the subject of productivity and the business of airlines, respectively. While my time here spent at MIT may be described nothing short of “drinking from a fire hose”, this thesis represents a portion of what I have learned and would not have been possible without the help and support of many of those around me, to only some of who are mentioned here.

Above all, my deepest gratitude goes to my advisor, Dr. Peter Belobaba, whose consistent feedback, guidance, and patience proved critical to my development and understanding of research. From enrolling in 1.232, The Airline Industry, to our research meetings, his knowledge of the airline industry and acute focus on details enabled me to achieve constant progress in completing this thesis.

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There were many other people that contributed both directly and indirectly to this piece of work that include: Aleida, for here unparalleled support and ensuring I maintained balance; Mareena, who unanimously won the “Accountability Partner of the Year” award and the entire ACME family for their constant words of encouragement and weekly boosts; Maurice, who was always there to listen to me vent and keep me level-headed; and even the noon-ball gang who provided some much needed pick-up basketball runs. Whether they are aware of it or not, all of them were crucial components for me achieving this accomplishment.

Lastly, I would like to thank my family – my mother and three sisters – who I dedicate this thesis to. I would have not been able to achieve any of this without their relentless support and unequivocal love. They continue to motivate me and remain at the forefront of all my future endeavors.

I take full responsibility for any errors or inadequacies that remain in this research.
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Chapter 1

Introduction

Since the passage of the Airline Deregulation Act of 1978, there have been substantial changes in the US airline industry. The dynamic environment spurred by the increased competition from new carriers demanded improved efficiencies or forced existing carriers out of business. The Air Transport Association’s records indicate there have been over 100 airline bankruptcies since deregulation [ATA, 2012]. From the record profits of the late 1990s to the turmoil caused by the attacks on September 11th, the effects of operating in a deregulated environment on US passenger airlines have led to the most recent wave of consolidation and bankruptcies, among others. One of the most highly touted effects of deregulation include the increased customer benefits, as fierce competition lowered fares. System-wide yield, a measure of the average fare paid per mile, declined nearly 50% in real terms from 1978 to 2009, which contributed to the rapid growth in air travel over the same time period [DOT, 2011]. Despite the tremendous growth in air travel and unprecedented load factors that exist today, air transportation remains one of the safest modes of travel.

Since 2000, Network Legacy Carriers (NLCs) responded to their Low-cost Carrier (LCC) counterparts by trimming cost per available seat mile, CASM, through bankruptcy protection, employee cuts, salary reductions, and reduced network capacity. At the same time, LCCs’ lower cost structures and cheaper fares enabled them to acquire a considerable share of the domestic market. How did these changes affect both individual US carriers and the overall US airline industry’s productivity?
Economic theory suggests that changes in productivity affect profits, prices, and employee compensation for an industry or firm. By achieving higher productivity, an entity produces more output with the same (or less) quantity of inputs, ceteris paribus, resulting in an increased difference between total revenues and total costs and thus higher profits. While sustained profits have not been the case for the majority of US carriers, both the post-deregulation transition and turn of the century challenges provide a basis for exploring productivity changes in the US airline industry.

Past studies of productivity in air transportation since deregulation date back to Caves, Christensen, and Tretheway (1983), which studied the effects of deregulation on the productivity of US trunk and local service airlines, to more recent studies of Oum, Fu, and Yu (2005) who studied both productivity and cost competitiveness for 10 major North American carriers. Furthermore, government agencies such as the US Department of Transportation’s Bureau of Transportation Statistics conducted numerous studies that compare both partial and comprehensive measures of productivity at the aggregate US airline industry level with those of the business and other transportation sectors Apostolides (2006). The majority of these studies either focus on the conventional Multifactor Productivity (MFP) or Total Factor Productivity (TFP) methods to compute and evaluate productivity performance; the primary difference is that the former (i.e., MFP) measures the ratio of a single output per combination of inputs and the latter measures the ratio of total output to total input. In addition, these studies measured productivity during fragmented and distant analysis periods.

Using recent available data, this thesis builds upon the rich literature by evaluating productivity using both MFP to measure US airline aggregate productivity over the long-term from 1978 to 2009 and TFP to measure both NLC and LCC carriers’ disaggregate productivity from 1995 to 2010.
1.1 Thesis Objective

The goal of this thesis is to examine productivity performance of US passenger airlines at the aggregate and disaggregate levels over the past three decades. While common partial measures are briefly discussed, this thesis focuses on two common methodologies used to measure comprehensive productivity. That is, the MFP methodology is applied to measure and compare productivity performance of the aggregate US airline industry level from 1978 to 2009 and the TFP methodology is applied to measure and compare productivity performance at the disaggregate US passenger airlines level from 1995 to 2010. In addition, because TFP measures ignore specific sources of productivity, regression analysis is applied to explore the underlying factors that help explain changes in TFP. Our interest is motivated by the various US airlines, both NLCs and LCCs, that have managed to survive through various challenges.

The improvements in airlines’ productivity performance over the last three decades has been overshadowed by their cyclical financial performance. By objectively evaluating improvements in productive abilities, we are able to measure the long-term technological progress that includes both managerial and organizational changes, among others. This thesis concludes that despite repeated challenges, US passenger airlines at the aggregate industry level and disaggregate carrier level have made significant productivity gains in the last 30 years.

1.2 Thesis Organization

The remainder of this thesis is organized as follows:

Chapter 2 begins with a brief discussion of productivity in general and the various techniques used to measure it. This chapter concludes with a discussion of the evolution of the airline industry since deregulation and how past literature has studied its affects, along with others, on productivity.
Chapter 3 describes the aggregate and disaggregate data set used to compute measures of productivity and focuses on output and input variables at the US airline industry and individual carrier levels.

Chapter 4 consists of a detailed discussion of the MFP methodology used to compute measures of productivity at the US airline industry level as well as our annual and cumulative MFP results from 1978 to 2009.

Chapter 5 describes the TFP methodology in detail and presents TFP measures for our studied NLC and LCC carriers from 1995 to 2010. This chapter concludes with a discussion of the potential effects of network variables on changes in TFP.

Chapter 6 summarizes our overall findings in regards to productivity performance at the aggregate industry level from 1978 to 2009 and the disaggregate carrier level from 1995 to 2010. A brief discussion of future research is included.
Chapter 2

Background and Literature Review

This chapter is separated into three sections. The first section includes a general definition of productivity and describes our approach to measuring it. The next section includes a brief discussion of the evolution of commercial aviation prior to and just after deregulation. The last section reviews the past literature on the evolution of productivity studies in air transportation and their popular methodologies.

2.1 Review of Productivity in the Airline Industry

2.1.1 Productivity Defined

In general, measures of productivity are computed as the ratio of the change in output to the change in inputs used to produce them and thus evaluate an entity’s production process. Diewert and Nakamura (2005) suggest envisioning the production process as a “black box” that takes in inputs on one side and produces outputs that are sold on the other. Productivity measures how well the black box turns quantities of inputs into quantities of outputs. An increase in productivity occurs with a variety of output and input changes that include the increase in input quantities (e.g., in the case of airlines more aircraft) to increase output and the increase in the efficiency of inputs (e.g., larger and faster aircraft) to increase outputs.
Importance of Productivity Gains

Economic theory suggests that changes in productivity affect profits, prices, and compensation for an industry or firm. Consequently, by achieving higher productivity, an entity produces more output with the same (or less) quantity of inputs, ceteris paribus, resulting in an increased difference in total revenues and total costs, and thus, higher profits. According to Kaci (2009), increases in airline productivity can benefit stakeholders through:

- Lower fares for customers;
- Increased tax revenues for government;
- Higher retained earnings for carriers;
- Increased dividends for investors; and
- Higher wages for employees.

However, as this thesis shows, improvements in productivity performance are not indicative of financial performance in the US airline industry, as sustained profits have eluded many carriers despite achieving increased productivity. The relationship between profits and productivity differs in how profits account for changes in prices and quantities and productivity accounts for quantity changes only. Productivity is one aspect of financial performance, among the ability to price above costs and reduce unit costs. As a result, due to the trade-off between various performance measures (i.e., productivity, input costs, and pricing ability), it is important not to confuse improvements in productivity as an indication of profitability. Thus, the inability to predict financial performance from changes in productivity serves as a limitation of gross measures of productivity (as discussed in Section 2.3.3).

2.1.2 Approach to Measure Productivity

While there is a broad consensus on the general concept of productivity, there are a variety of ways to measure it that can lead to different interpretations and empirical
results (Oum, Tretheway, and II 1992). This thesis measures productivity at the industry and firm level to evaluate and compare changes in productivity across carriers and over time. Measures of productivity are categorized as single factor (partial) or multifactor (comprehensive) measures. Partial measures compare the change in one or more output categories to the change in some, but not all input categories. Common single factor productivity measures used in the airline industry are aircraft and labor productivity. These measures, used to compare operational efficiencies among individual carriers, can be misleading when describing the overall efficiency of an airline due to the interdependence of inputs. For instance, if a carrier that invests in capital to improve labor efficiency (i.e., produce more ASMs with fewer employees), then overall productivity is not necessarily higher. Consequently, we focus on comprehensive measures of productivity to account for all inputs and thus provide an assessment of both the US airline industry and individual carriers’ productivity changes.

By including all inputs to measure productivity, comprehensive measures capture the relative importance of several factors of production that often shift over time. For example, although historically labor expenses represented the largest portion of an airline’s total operating expenses, the increase in fuel costs reduced their share of total operating expense.

2.1.3 Multifactor and Total Factor Productivity

To produce aggregate measures of productivity at both the airline industry and individual carrier levels, we applied non-parametric index techniques that allowed estimation directly from data, opposed to parametric techniques (e.g., production or cost function) that required statistical estimation. However, statistical analysis was applied to decompose gross measures of individual carriers’ change in productivity.

The two primary approaches used in this thesis to generate gross measures of productivity include: the basic accounting methodology, referred to as the Multifactor Productivity (MFP) methodology, and a direct quantity index methodology, referred to as the Total Factor Productivity (TFP) methodology. Both methodologies compute
measures of productivity referred to as MFP and TFP measures, and thus these terms are used interchangeably with productivity throughout this thesis. To differentiate the two types of productivity measures used in this research, Diewert and Nakamura’s (2005) references are adopted:

- MFP is defined as the ratio of a single measure of output quantity to a measure of the quantity of a bundle of inputs; and

- TFP is defined as the ratio of a measure of total output quantity to a measure of total input quantity.

It is important to note that although some studies use MFP and TFP interchangeably, hereafter, this research distinguishes between the two types to avoid confusion and emphasize the single output measure used in the MFP methodology versus the total output measure used in the TFP methodology.

**Multifactor Productivity**

Multifactor productivity relates a single output to a combination of resources used to produce it. That is, MFP measures the growth in output that cannot be attributed to changes in factors of production (inputs) by subtracting the change in share-weighted inputs from the change in outputs. After the MFP method removes the contribution of primary inputs, the residual represents a gross measure of productivity that includes the growth in output due to the use of technology, managerial and organizational changes, and other quantities difficult to measure. Thus, MFP is a broad measure of technological progress that includes improvements in the organization of the production process, quality of inputs, advances in technology, and the use of information technology, to name a few. A detailed discussion of MFP is included in Chapter 4.

In the case of airlines, the primary service (output) delivered is moving passengers from point of origin to destination via aircraft. The delivery of service may simply be quantified as the number of passengers transported in a year (i.e., enplanements).
However, a more appropriate measure of output that accounts for the distance passengers are flown is revenue passenger miles (RPMs), a measure of airline traffic, defined as one revenue passenger flown a distance of one mile. In addition, output may be measured in available seat miles (ASMs), a measure of network capacity, defined as one available seat flown a distance of one mile. One could argue that empty available seats (ASMs) without revenue-paying passengers (RPMs) is a misleading measure of an airline’s output and vice versa. For instance, if the airline industry continued to expand its network capacity (i.e., increase output) without a similar increase in airline traffic, productivity measures may be overstated. On the contrary, the increase in airline traffic relative to network capacity, also known as the average system-wide load factor, may understate the improvements in productivity depending on the output measure assumed. For these reasons, the MFP methodology applied in Chapter 4 computes measures of productivity in terms of both RPMs and ASMs.

**Total Factor Productivity**

TFP measures are computed for individual carriers by aggregating output and input variables into a single measure. To overcome the difficulty in accounting for all outputs (or inputs) in a single measure, the *trans-log multilateral index procedure* proposed by Caves, Christensen, and Diewert (1982), is applied. This Tornqvist methodology uses revenue and cost shares as weights when aggregating outputs and inputs. A more detailed discussion of Caves et al.’s (1982) method is included in Chapter 5.

One of the advantages of TFP measures include the ability to compare changes in productivity between carriers for a particular time period, over time for a particular carrier, or a combination of both. Individual TFP levels are of little to no value unless combined with a reference (e.g., year or carrier), and therefore, TFP levels are computed and chained relative to a base period.

**2.1.4 Limitations of Productivity Measures**

Limitations of gross measures of productivity using the MFP and TFP methods include: limited accuracy, sensitivity to year-to-year changes, and the inability to
assess financial performance.

By definition, productivity ratios are highly affected by changes in both the numerator (output) and denominator (input). Thus, various combinations of output and input changes may affect productivity levels and reduce overall accuracy. To ensure changes in productivity only occur in response to physical quantity shifts, output and input indices are constructed using constant values to control price changes over time. Productivity growth is highly dependent on the choice of comparison scenario. However, the TFP methodology (see Chapter 5) contains specific characteristics that overcome this issue and allow for similar productivity comparisons, irrespective of the base period selected.

Annual changes in productivity reflect cyclical changes in the economy and thus may lead to erratic year-to-year measures. Because of these year-to-year variations, a series of long-term periods is more reliable in evaluating changes in productivity. Consequently, we measure both annual and cumulative changes in productivity.

A major limitation of productivity measures is the inability to assess profitability, a carrier’s ultimate goal. Financial performance is a function of pricing, production abilities, and cost competitiveness. While improving productivity does reduce unit costs and therefore improve carriers’ cost competitiveness, the latter is a function of changes in both physical quantities (productivity) and changes in input prices. Although both measures of profitability and productivity have similarities, inferences in regards to profitability from productivity performance are often misleading. Productivity is a performance concept that explores changes in physical quantities by controlling the effects of price changes (constant prices). On the contrary, profitability is an accounting concept that uses current prices to reflect changes in both quantities and prices. That is, in addition to productive ability, financial performance is a function of the ability to price above costs and minimize costs. Although the changes in average yield and unit costs for the US airline industry are briefly explored in Chapter 4, this thesis focuses on examining changes in overall productivity performance.
2.2 Evolution of Commercial Aviation

2.2.1 Early Commercial Aviation

Early carriers such as United (UA), American (AA), Eastern (EA), and Transcontinental and Western Air (TWA) served as pioneers in the transition from mail to passenger service in the US domestic market. Although commercial aviation can be traced back to the mid-1920s, the Civil Aeronautics Act of 1938, which created the Civil Aeronautics Board (CAB), was the first major effort to regulate US commercial aviation. The primary functions of CAB included awarding access to routes, regulating passenger fares, and limiting entry into markets. The US airline industry’s regulatory framework and highly unionized workforce offered weak incentives for cost minimization. In addition, high fares limited the number of people who could travel and thus reduced carriers’ ability to utilize capacity. These inefficiencies were exacerbated by the weak economic growth in the early 1970s.

Capacity increases enabled by the introduction of jet and wide-body aircraft led to immense challenges with the recession in the 1970s and increased fuel prices in response to the Oil Crisis of 1973. To deal with the excess capacity coupled with the reduced demand for air travel, the CAB responded with a four year moratorium on offering new services and granted carriers the ability to raise fares to cover increased costs [Meyer, Oyster, Morgan, Berman, and Strassmann, 1981]. Consequently, the public’s dissatisfaction reached its peak as strains on the industry and support for regulatory reform increased. Furthermore, the need to reform was supported by the empirical evidence of low-cost domestic and international flying. [Baltagi, Griffin, and Rich, 1995] noted the key role that past literature played in “dismantling a gargantuan regulatory complex.” Studies such as Caves (1962) and Douglas and Miller (1974) emphasized the inefficiencies promoted by regulation, while others highlighted the fact that fares within states were cheaper than fares between states of similar distances (as cited in Baltagi et al. (1995)).

With the support for regulatory reform and the leadership of newly appointed CAB Chairman Alfred Kahn, the Airline Deregulation Act of 1978 was enacted to
lower barriers to entry and allow pricing and route freedoms. Proponents argued that removing government intervention would lead to more competition and thus positively impact the industry through reduced fares for passengers and increased service to various markets.

**The Deregulated Environment**

By fostering competition among carriers, deregulation led to improvements such as the entry of successful LCCs and consumer benefits in the form of lower fares, all while maintaining safety [Belobaba, Odoni, and Barnhart 2009]. On the contrary, negative effects included the loss of service to smaller communities as early subsidies, paid to carriers who served such markets, expired [Meyer et al. 1981]. However, service in these smaller markets was eventually replaced by regional airlines. Although the airline industry was highly unionized, deregulation reduced labor power as new entrants could better control costs with non-unionized and often cheaper labor costs. The competitive environment forced airlines to become more efficient or be forced out of business. Popular airlines that existed pre-deregulation such as Pan Am and EA, eventually disappeared. Just after the turn of the 21st century, only two (i.e., UA and AA) of the four early pioneers in US passenger air travel remained. However, various airlines that started pre-deregulation has continuously overcame three decades of ongoing challenges to remain relevant and competitive.

Although regulation in the airline industry limited the number of carriers and required strict mandates to serve particular markets, a considerable number of carriers existed during this period. Figure 2-1 shows a time-line of various carriers that entered and exited the US market since the early 1920s. Although this is not an exhaustive list of airlines, the figure attempts to provide an overall snapshot of the transition of key carriers who entered or exited the US airline industry. The first wave of airlines appeared in the mid-1920s to early 1930s with the birth of early pioneers (AA, TWA, EA, UA) and other carriers such as Continental and Braniff. The next major wave of new carriers pre-deregulation occurred in the late 1940s to early 1950s, with the addition of carriers such as Alleghany, Midwest, and North Central.
<table>
<thead>
<tr>
<th>Year Range</th>
<th>Airlines</th>
</tr>
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<tbody>
<tr>
<td>1920-1929</td>
<td>Capital Airlines 1928-1961</td>
</tr>
<tr>
<td>1930-1939</td>
<td>United Airlines 1926-Current</td>
</tr>
<tr>
<td>1940-1949</td>
<td>N.Y.A.</td>
</tr>
<tr>
<td>1960-1969</td>
<td>Midwest Airlines 1948-Current</td>
</tr>
<tr>
<td>2000-2009</td>
<td>Empire</td>
</tr>
<tr>
<td>1920-1929</td>
<td>Hawaiian 1929-Current</td>
</tr>
<tr>
<td>1930-1939</td>
<td>Braniff Airways 1928-1982</td>
</tr>
<tr>
<td>1940-1949</td>
<td>Eastern 1926-1991</td>
</tr>
</tbody>
</table>

**Figure 2-1: Change in US Carriers Over Time**
With the exception of a few carriers such as Southwest Airlines, which started operations in 1971, the next major wave of carriers occurred post-deregulation with the entrance of start-up carriers such as People Express (PE), Midway (MW), and New York Airlines (NYA). Apart from previous new entrants, these carriers, often referred to as “low-cost, no-frills” or “discount” carriers, aimed to offer competitive service in their respective markets at a cheaper price. The entrance of these new discount carriers combined with other obstacles that included economic downturns and increasing costs posed major challenges for some carriers that existed prior to deregulation. For instance, Braniff Airlines, which started operations in the late 1920s, was forced to file for bankruptcy protection in the early 1980s immediately following deregulation. Although Braniff resumed operations in 1984 under new management, the airline would continue to struggle and be forced into its second bankruptcy in the late 1980s. Overall, the entry and exit of various carriers throughout the past three decades reflect how direct competition in the US market coupled with increased costs forced productivity improvements in the form of bankruptcies and mergers, to name a few.

Of the LCCs that existed in 2010, with the exception of Southwest, the majority of them which include jetBlue, AirTran, and Frontier, entered in the mid-1990s to early 2000s. In addition, carriers formed pre-deregulation such as Delta, American, and United Airlines (often referred to as “trunk airlines,” “NLCs,” or simply “legacy carriers”) remained viable and competitive airlines, as of 2010.

In regards to the “success” or “failure” of deregulation, past studies report evidence deregulation was the right move that resulted in far more winners than losers. In fact, there is a rich literature of early studies devoted to evaluating US deregulation effects by comparing the productivity of US carriers to those of international markets which had yet to be liberalized. The success of US deregulation efforts is supported by the liberalization of international markets that would follow in the late 1980s to early 1990s. Windle (1991) compared US and international airlines and found that the higher density (more passengers traveling along a given route) of US carriers, a direct effect of deregulation, resulted in lower unit costs and thus higher efficiencies.

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In addition, Windle (1991) claimed that government ownership led to excessive use of inputs (often labor) to produce an equivalent quantity of output. A 2006 study by the US Government Accountability Office (GAO) further highlighted the benefits of deregulation and recommended against re-regulating the airline industry (GAO, 2006). Furthermore, Baltagi et al. (1995) looked at the impact of deregulation on costs in the airline industry in terms of productivity performance and found that deregulation significantly reduced union wage rates, led to faster output growth for non-trunk airlines, and had a pronounced effect on route structure (i.e., increase stage length and hubbing). More evidence on the various advantages and disadvantages in regard to productivity performance is included in the following section.

2.3 Literature Review

Productivity is a broad performance concept that was widely studied in the airline industry even before deregulation. Since the early 1970s, productivity studies have evolved in the carriers studied, time periods analyzed, and theoretical methodologies applied. Early studies aimed to differentiate sources that led to productivity changes that can be attributed to returns to scale (e.g., increase network size) and shifts in productive abilities (e.g., managerial and organizational changes), to name a few. The latter (i.e., shifts in production abilities), is what economists think of as productivity (Oum et al., 1992). This theme of identifying specific sources of productivity has continued in much of the current literature. However, given that productivity measures computed are “residuals” that encompass a variety of sources, studies such as Baltagi et al. (1995) admit it is challenging to explain changes in productivity that may be credited to measures difficult to quantify, such as deregulation and technological progress.

This literature review examines how past studies of productivity in the airline industry have developed and their main conclusions. Past studies that applied MFP to measure and compare airline productivity performance at the aggregate (i.e., airline industry) level are briefly mentioned. Then, early studies of TFP in air transportation
and how they evolved over time are described. Finally, the current state of productivity research is explained based on what previous studies have found regarding the transition of US passenger airlines after deregulation and the turn of the century impact on their productivity performance.

2.3.1 Common Measures of Productivity

The most common approaches used to measure airline productivity in the literature range from the basic accounting methodology framework to more econometric-based. Apostolides (2006) applied a basic accounting methodology to examine changes in MFP for the US airline industry from 1990 to 2001. In addition, this study compared MFP and labor productivity between US airlines, transportation sub-sectors (i.e., trucking and rail), and the private business sector. The author concluded both MFP and labor productivity increased over the 1990-2001 time period although the second half of the 1990s experienced lower to no growth. Compared with the US private business sector, this study found MFP in air transportation increased at a faster rate after 2003.

Although the basic accounting methodology is commonly used by government agencies to compute aggregate measures of MFP at the US airline industry level, the majority of past studies measure TFP using parametric or non-parametric approaches (Oum et al., 1992). The latter (i.e., non-parametric techniques), allow productivity measures to be constructed using data opposed to parametric techniques that require statistical estimation of a cost or production function. This thesis focused on the use of non-parametric techniques. Specifically, the use of direct quantity indexes such as the trans-log multilateral index procedure proposed by Caves et al. (1982).

The trans-log multilateral index procedure is the most common methodology applied throughout past studies. For simplicity when referring to the Caves et al. (1982) methodology, this section refers to it as CCD’s methodology. The majority of the literature refers to TFP as the single most useful measure of productive efficiency (Windle (1991) and Caves et al. (1983)). Thus, unless otherwise noted, hereafter the terms productivity and TFP are used interchangeably.
2.3.2 Evolution of Productivity Studies

Early Studies

There are various studies that measure and compare airline productivity performance that date back to before deregulation. Past studies range from evaluating productivity performance of US versus non-US carriers, while others focus solely on the US environment. Early studies measured and evaluated the change in productivity performance to determine the effects of deregulation on airlines’ efficiencies.

Caves et al. (1983) measured TFP growth of US trunk and local carriers from 1970 to 1980. This study applied CCD’s methodology and claimed TFP is the “best single measure of productive efficiency.” Results indicate TFP growth accelerated from 2 to 5 percent per year during the deregulated period (1976-1980). In addition, regression analysis was applied to identify specific sources that help explain such changes in productivity. Explanatory variables were identified using TFP growth rates regressed on measures of output, capacity, and controllable network variables such as load factor and stage length. This study found that the acceleration of TFP following deregulation (1976 to 1980) is explained by output, load factor, and capacity. Output was identified as the key factor in explaining the acceleration of TFP. Average stage length was found to be insignificant, and in some cases the estimated coefficient was counter-intuitive. Overall, Caves et al. (1983) used measures of TFP to evaluate if deregulation led to productivity improvements in the airline industry.

Baltagi et al. (1995) investigated the impact of deregulation on TFP using a sample of 24 US airlines from 1971 to 1986 to explore efficiency changes as a result of deregulation, technological progress, or a combination of both. This study admits it is difficult to compare the linkage between technology, technological innovation, and deregulation. However, the authors disproved a counter-argument by Gordon (1990), who found no evidence that attributed productivity growth to deregulation (as cited in Baltagi et al. (1995)). The results of this study indicate deregulation significantly reduced union wage rates, led to faster output growth for non-trunk airlines, and had a pronounced effect on route structure (i.e., increase stage length and hubbing).
The authors claim productivity would have grown more slowly in the absence of deregulation because of its enabling affects with improvements in capital stock (e.g., fuel-efficient aircraft), increased load factors, and development of hub operations.

To compare carriers operating in both competitive and non-competitive environments, Windle (1991) extended the previous study done by Caves et al. (1983) by examining TFP and unit cost differences among US and non-US airlines. The non-US airlines were used as a control group to evaluate deregulation effects on US carriers operating in the newly competitive environment. In addition, this study decomposed a previous cost function analysis by Caves et al. (1987) to identify specific sources of productivity changes to determine what forms of deregulation would have increased productivity for the non-US environment (as cited in Caves et al. (1983)). The results of this study indicate that although US carriers had higher productivity gains in the specified year (1983), these gains were offset by higher labor costs. Implications from this study focused on the need to increase traffic density (more passengers traveling on a particular route) through some form of deregulation that enabled increased demand, reduced fares, network re-configuration, and restructuring.

Using a different approach than the popular CCD’s methodology, Distexhe and Perelman (1994) applied Data Envelopment Analysis (DEA) to measure productivity growth using a panel set of 33 international airlines from 1977 to 1988. Although the DEA approach is not used in this thesis, this study identified some key conclusions worth noting. This study argued changes in route network density and load factors are the “best indicators” of US airlines’ response to deregulation and the success of this response, respectively. The results of Distexhe and Perelman (1994) indicate carriers who operated worldwide (e.g., legacy carriers) witnessed a general improvement in technological efficiency in the 1980s. Consequently, carriers that operated on a lower scale were often condemned to merge or purchased by a larger airline.

Overall, early studies assessed the various policy regimes of the US versus non-US aviation markets. In general, most studies agreed that US passenger airlines experienced the highest productivity gains with increased competition and route and pricing freedoms, prior to the liberalization of international aviation markets. That
is, deregulation allowed US carriers to achieve higher productivity than their international counterparts, despite the latter’s lower labor costs. However, the productivity gap between US and non-US carriers closed significantly since liberalization of European aviation, which started in the late 1980s. Some studies show the availability of cheaper labor and substantial unit cost savings of international airlines enabled them to surpass US carriers in productivity levels. For instance, Windle (1991) concluded Singapore Airlines was number one in both productivity and unit costs at the time of the study, explained by cheaper labor prices, longer stage length, and the diminishing traffic density advantages in the US market. Oum and Yu (1995) found evidence of “substantial productivity gains” for non-US carriers over the 1986 to 1993 time period since liberalization. While comparing carriers worldwide may be of interest in evaluating how airlines compete on a global scale, this thesis focuses on US commercial aviation.

Recent Studies

After the mid-1990s, commercial aviation worldwide operated under a highly competitive environment with some form of deregulation or liberalization, and thus, past studies evolved from assessing policy regimes of international markets to decomposing productivity gains (or losses). That is, a recent theme of productivity studies aims to distinguish changes in productivity that can be attributed to changes in productive abilities (i.e., innovation) from other sources such as returns to scale (Oum et al., 1992).

Oum and Yu (1995) measured and compared TFP performance of 23 of the world’s major airlines from 1986 to 1993 to examine changes in cost and productivity performance using CCD’s methodology. As previously mentioned, the authors reported that while US carriers on average have higher productivity levels, the newly industrialized countries were achieving much higher growth rates thus diminishing the overall productivity gap. To identify factors that affected TFP changes, regression models of TFP growth rates were estimated and their results indicated the change in TFP levels were explained by changes in output and stage length. However, the authors
admitted due to the positive correlation between stage length and load factor, the contribution of both variables may be overstated or vice versa.

While the majority of past studies were conducted prior to the turn of the 21st century, there are a few recent studies worth noting that focused on measuring and comparing productivity performance among US carriers and thus serve as a direct comparison to this thesis.

Oum, Fu, and Yu (2005) applied CCD’s methodology to measure and compare productivity performance among a sample of US carriers from 1990 to 2001 in order to capture the unforeseen events that transpired after 2000 such as the attacks on September 11th. The authors claimed carriers improved their productivity over the entire period despite rising input prices. Furthermore, this study reported evidence of declining productivity, yield, and unit costs as a result of the September 11th attacks.

Homsombat, Fu, and Sumalee (2010) examined changes in productivity and cost competitiveness of US carriers from 1990 to 2007 using CCD’s methodology and applied regression analysis to identify key factors that led to such changes. The authors reported bankruptcy protection enabled many carriers to improve productivity levels above the industry’s average. While this study found significant productivity improvements from 1990 to 2007, they also noted how efficiency gains were largely offset by the increase in fuel prices. Similar to Oum and Yu (1995), this study also found negative correlation between productivity improvements and labor costs, which implies that as labor costs were reduced, productivity improved.

In terms of convergence of productivity levels among carriers competing in similar markets, Oum and Yu (1995) reported evidence of convergence over the sample period (1986-1993), while Homsombat et al. (2010) found no evidence over a longer analysis period (1990-2007). The results of both studies in regards to convergence of productivity levels were explored in this thesis, as product differentiation remains a major strategy for US carriers to remain competitive.
2.3.3 Limitations of Past Studies

Limitations of early studies include the use of time periods shortly after deregulation and the use of short analysis periods highly sensitive to year-to-year fluctuations, which consequently could have yielded misleading results. For instance, Distexhe and Perelman (1994) found no evidence of productivity gains for US carriers coming from structural changes in route networks, most likely due to airlines still adapting to the deregulated environment. The emergence of hub-and-spoke networks was early during this time period and thus may have had minimal effects on productivity gains. Moreover, short analysis periods were highly sensitive to year-to-year fluctuations that may not be generalized outside of the analysis period. For example, Caves et al. (1983) included observations of 15 major strikes (defined as 25 or more days) in the 1970 to 1980 time period, which may have negatively affected the study’s sample data.

With the exception of Homsombat et al. (2010), none of the aforementioned studies evaluated productivity performance after the early 2000s. As a result, most of the past studies excluded the impact of low-cost carriers such as Southwest, jetBlue, and AirTran. Furthermore, none of the studies evaluated productivity performance of the US airline industry over a long-term period from deregulation to the 21st century.

While it is true deregulation resulted in some immediate effects, many would argue the “true” effects of deregulation did not happen until the turn of the century. Graham, Kaplan, and Sibley (1983) discussed the increasing role of LCCs in contributing to a more efficient industry and agreed that the majority of the studies chose analysis periods when the industry had not yet fully adapted to the competitive environment. Furthermore, Good, Roller, and Sickles (1993) agreed that the full benefits of deregulation had not been observed by the 1990s and the industry was not completely competitive.
2.3.4 Literature Review Conclusion

Overall, past studies range from using measures of productivity to determine the effects of deregulation (Caves et al., 1983) to comparing productivity performance across major airlines worldwide during periods of rapid change (Oum and Yu, 1995). Study periods just after deregulation serve as a major drawback of such studies and thus provides an opportunity to re-evaluate and compare changes in productivity between low-cost and legacy airlines. The most popular methodology used to measure TFP is the trans-log multilateral procedure proposed by Caves et al. (1982). This methodology is cited in the majority of the early and current literature and thus is applied in Chapter 5. Changes over the 2000 to 2010 period, including the use of the Internet for sales and distribution, the bankruptcies of four of the “Big 6” US carriers, and the impact of LCCs, all played key roles in evaluating productivity changes.

2.3.5 Research Contribution

This thesis contributes to the rich body of literature in the following ways: (1) use of the 1978 to 2009 time period allows us to take a comprehensive snapshot of how deregulation has affected the entire industry opposed to the fragmented study periods of past studies and (2) this research uses more recent data (post-2000), when major changes had drastic effects on the industry’s productivity performance. To accomplish these objectives, this research utilizes both MFP and TFP methodologies to measure changes in productivity at both the aggregate airline industry and disaggregate carrier levels.
Chapter 3

Industry and Carrier Data

This chapter is divided into two sections that include a general description of data collected on outputs, inputs, and financial information to measure productivity in this thesis. The first section describes aggregate airline industry trends and the last section concludes with a brief description of the disaggregate carrier level data. To measure productivity at the aggregate and disaggregate levels, detailed data on output, input, network, and operational attributes were collected for US passenger airlines from MIT’s Airline Data Project which, in turn, was extracted from publicly available data published in the US Department of Transportation’s Bureau of Transportation Statistics (BTS) Form 41 database [DOT 2011].

3.1 Aggregate Industry Data

The basic accounting methodology, referred to in this thesis as Multifactor Productivity (MFP), was used to compute gross measures of productivity at the US airline industry level. Relevant data included information on industry capacity, traffic, and financial performance from 1978 to 2010. Measures of output include: RPMs (i.e., one revenue paying passenger flown one mile); ASMs (i.e., one available seat flown one mile); and RTMs (i.e., amount of tonnage including cargo and passengers multiplied by distance flown). The inputs used to produce such outputs were categorized as labor, fuel, capital, and intermediate purchases. The intermediate category cap-
tures other expenses (i.e., interest, insurance, maintenance, outsourcing etc.) that may not be classified in the other categories. Although inputs may be measured in various ways (e.g., labor hours, gallons of fuel), we measured aggregate inputs in constant dollars. Because MFP relates the change in output to the weighted share of inputs, shares for each respective input was computed as a percent of total operating expenses (TOE) excluding transport related fees. Total operating expenses only include costs that directly contribute to output production (i.e., produce ASMs, RPMs, or RTMs). Transport related expenses, paid to a particular airline’s regional partners to transport its traffic, produce no additional output and thus are excluded from all calculations.

3.1.1 Airline Output and Input

The evolution of aggregate outputs and inputs are explored in the following section to identify patterns that help explain changes in aggregate productivity measures. It is important to note this chapter presents aggregate data for the airline industry from 1978 through the third-quarter of 2010. However, in order not to understate, or vice-versa, the effects of missing data in 2010, MFP measures computed in Chapter 4 focus on the 1978 to 2009 time period. To compare changes over time, unless otherwise noted, CPI-adjusted data are presented.

Airline Industry Outputs

Figure 3-1 shows the relationship between the airline traffic (RPMs) and network capacity (ASMs) outputs used to compute MFP. Both airline traffic and network capacity increased significantly from 1978 to 2009. Airline traffic nearly tripled while network capacity more than doubled in the same time period. As both airline traffic and network capacity increased at similar rates in the 1980s, load factors (RPMs/ASMs) remained stable around 60%. Starting in the 1990s, airline traffic increased at a slightly faster rate than network capacity and thus load factors increased to 70% and continued increasing throughout the 2000s to an unprecedented high around 80%. While both RPMs and ASMs constantly increased the majority of the analysis pe-
period, dips coincided with periods of economic downturns and other unforeseen events such as the Gulf War of the early 1990s and the attacks on September 11th in 2001.

![System-wide Traffic (RPMs) and Capacity (ASMs) and Load Factors](image)

Figure 3-1: System-wide US Passenger Airlines’ Network Capacity and Traffic (DOT, 2011)

**Labor Input**

Weak economic conditions, expensive labor contracts, and the increases in fuel costs all played key roles in the tremendous labor cuts that occurred in the early 2000s. Figure 3-2 shows labor expenses and their cost shares of TOE. Labor expenses grew about 20% over the first two decades of the analysis period before peaking in 2000. A portion of this increase in labor expenses can be explained by employee growth in the same time period. After 2001, when labor costs represented just over a third of TOE, labor expenses were reduced as the number of employees were drastically cut. As of 2009, labor expenses represented about 25% of the industry’s TOE as a result of employee reductions and the change in other inputs (e.g., increase in fuel costs).
Figure 3-2: US Airline Industry’s Aggregate Total Labor Expenses (DOT 2011)

Fuel Input
Fuel expenses and their cost share of TOE decreased in the early 1980s (slight increase late 80s early 90s), stabilized in the mid- to late 1990s, and rapidly accelerated in the 2000s. Figure 3-3 shows fuel expenses and their share of TOE over time. Since 1980, fuel expenses declined or remained fairly flat (except for the slight jump in 1990) until the turn of the 21st century. From 1980 to 1989 and 1990 to 1999, on average, fuel expenses grew approximately 4.6% and 1.8% per year, respectively. The 2000 to 2009 period experienced an average annual growth of 16.3% in fuel expenses, reflected by the 204% jump in fuel cost per gallon from 2000 to its 2008 peak. As of 2009, fuel expenses were 87% above 2000 levels and therefore, fuel prices consumed a larger portion of carriers’ TOE in this same time period relative to previous decades.

Capital Input
As shown in Figure 3-4, from 1980 to 1995, capital expenses increased about 150% and continued to increase until its peak in 2001, with a short stable period in the
mid-1990s. Capital expenses represented about 16% of TOE in 2001 with a 25% increase between 1997 and 2001, as the airline industry continued to grow (see Figure 3-1). A large portion of the increase in capital expenses can be explained by the change in aircraft rental costs. Prior to 2000, aircraft rental costs, which represented on average 60% of total aircraft costs since 1990, almost doubled (91%) from 1990 to 2000. After 2002, as aircraft rental costs declined 20% between 2000 and 2009, US carriers significantly reduced their capital expenses in the same time period. This decline in aircraft rental costs that resulted in reduced capital costs for airlines are most likely explained by the negative effects of the weak economic conditions that cascaded throughout the airline industry to suppliers and thus increased US carriers negotiating power.
Intermediate Input

Figure 3-5 shows the decrease in intermediate expenses (i.e., insurance, interest, food, outsourcing, etc.) since the late 1980s and the drastic dip in the early 2000s to their lowest point of the analysis period. This reduction in intermediate expenses can be attributed to the increased use of technology and organizational and managerial changes. For instance, US carriers experienced tremendous cost savings from areas such as commission costs and the use of technology to decrease maintenance costs. With industry expansion in the first few decades of the analysis period coupled with the increased pressure to control costs after 2000, intermediate purchases such as food and beverage expenses were further reduced to an average of 20% of TOE in 2009.

In summary, patterns in the US airline industry’s aggregate outputs and inputs help explain changes in productivity performance at the aggregate industry level, as discussed in Chapter 4. With a tremendous growth in traffic and network capacity since deregulation, the unforeseen changes in the 2000s forced carriers to become

Figure 3-4: US Airline Industry Aggregate Total Capital Expenses (DOT, 2011)
more disciplined with capacity expansion and demanded carriers’ improve their overall efficiency.

3.2 Disaggregate Carrier Data

This section includes a general description of the output and input variables collected on individual US passenger airlines from 1995 to 2010 to compute gross measures of TFP. In addition, individual carriers’ network control variables were collected to estimate sources that explain changes in productivity among carriers. Both changes in TFP and their sources are discussed in detail in Chapter 5.

3.2.1 US Carrier Profile

The data set used in this thesis to compute individual measures of TFP include both NLC and LCC carriers that provide both domestic and international services, with a
significant focus on providing scheduled passenger service. Carriers that are mainly engaged in cargo or charter services are excluded. There are large variations in terms of revenue, traffic, and other characteristics both within and across carrier types. In general, NLCs transported the majority of airline traffic and thus generated on average more revenue than LCCs. The size of our studied airlines, measured by operating revenue, range from just over US $24 billion for Delta and US $1 billion for Frontier Airlines. In regards to the origin of traffic transported, NLCs on average produced a third of their traffic internationally. With the exception of jetBlue, most of the LCCs focus on providing domestic service. With the increased emphasis on international traffic for NLCs, stage lengths on average are longer than LCCs. However, LCCs such as jetBlue and Alaska have competitive stage lengths to take advantage of economies of distance. On average, both load factor and output mix remained the same for all carriers at about 80% and 90%, respectively. Overall, although there are variations in carrier size, US airlines focused on providing scheduled passenger service as indicated by the percent share of passenger revenues, computed as passenger revenue divided by total operating revenue. For a detailed description of key characteristics of both NLC and LCC carriers, refer to Figure 5.1 of Chapter 5.

The Key Factors: Outputs and Inputs

Understanding changes in productivity requires details on an airline’s specific outputs and inputs. Outputs may be defined as those services produced by a specific carrier that provide value to the overall production process, i.e., services that generate revenue for the airline that include:

- Passenger revenue;
- Baggage fees;
- Cargo revenue;
- Cancellation fees; and
- Incidental (non-core activities) revenue.
Outputs are categorized as: (1) scheduled revenue passenger-miles; (2) scheduled revenue ton-miles of freight; (3) scheduled revenue ton-miles of mail; and (4) incidental revenue. The incidental revenue category includes revenues (i.e., baggage, cancellation, and miscellaneous fees) that are not part of the core revenue streams (e.g., passenger or freight) of the airline and thus does not fit into any other category. Respective shares for each category are calculated as a percent of total operating revenue reported in a particular year. With the exception of the incidental category, each output has a physical quantity (volume) and a share of total revenue (value) component. The use of constant prices ensure productivity changes reflect the change in physical quantities only. To include the incidental revenue category, which includes revenues that may not be associated with a physical quantity, an incidental quantity index weighted by its particular share was constructed (as discussed in Chapter 5).

Similarly, inputs are defined as the resources used to produce services (output) and thus accrue expenses for a particular airline that include:

- Labor;
- Capital;
- Fuel; and
- Materials.

Inputs are categorized as (1) labor; (2) fuel; (3) capital; and (4) intermediate purchases. Similar to the incidental output category, the intermediate category includes all costs (i.e., materials, insurance, outsourcing, etc.) that could not be categorized as labor, fuel, and capital. Due to the inability to associate a particular quantity to the intermediate category, an intermediate quantity index weighted by its cost share of TOE was constructed (see Chapter 5). The labor category includes information on each carriers’ full-time equivalent employees and their cost share of TOE. The fuel input category includes the annual number of gallons consumed for all aircraft types and their cost share of TOE. Similarly, the capital category consists of information on the the total number of fleet reported for each carrier and its cost share of TOE.
Capital costs include both aircraft and non-aircraft ownership costs. Aircraft ownership costs include rental and depreciation and amortization costs. It is important to note that previous literature constructs the capital category differently by using annual lease prices of various aircrafts as weights with corresponding aircraft types within each carriers’ total fleet. While this may improve the quality of the capital category, data on annual lease prices for specific aircraft were not readily available and could fluctuate depending on the source. By using total fleet and aircraft ownership costs, our capital category serves as a first-order approximation that accounts for both leased and owned aircraft of a particular carrier.

As described in Chapter 5, individual output and input categories are aggregated into a single measure, referred to as a multilateral output (input) index, using revenue shares (cost shares) for each respective output (input) as weights. Questionable data was cross-checked with a secondary source such as airlines’ annual reports and analyses were performed with and without questionable data.
Chapter 4

Multifactor Productivity in the US Airline Industry

This chapter measures and describes multifactor productivity (MFP) in the US airline industry from 1978 to 2009. The relationship between airlines’ change in output and the resources used to produce it is examined annually and cumulatively using measures of MFP computed by the basic-accounting methodology introduced by Solow (1957). In addition, we compare MFP with common single factor productivity measures. To compute aggregate measures of productivity, we collected system-wide data on US NLCs and LCCs from the Department of Transportation’s Bureau of Transportation Statistics Form 41 database (DOT, 2011). Relevant data included information on industry capacity, traffic, and financial performance from 1978 to 2009.

4.1 MFP Discussed

Whereas single factor measures of productivity (e.g., labor productivity) relate the change in output to the change in a single input, MFP relates the change in output to a combination of inputs (Duke and Torres, 2005). The combined input component of MFP aggregates all input variables into a single measure using their respective shares of TOE as weights to represent shifts in input contributions that change over time.
Although both single- and multi-factor productivity measures include similar influences (e.g., demand for air travel), MFP explicitly accounts for the interdependence of input measures by weighting inputs by their respective share of TOE. Thus, opposed to productivity improvements from just increasing input quantities, the MFP residual “...reflects only changes in overall efficiency that are due to other unmeasured influences” (Duke and Torres, 2005, p.33). These “unmeasured” influences include advances in technology and managerial and organizational changes among others. MFP residuals do not distinguish between unmeasured influences and therefore, the unexplained output growth represents a broad measure of the industry’s long-term technological progress.

The basic growth-accounting methodology, hereafter referred to as the MFP method, was commonly used in economic studies to examine the contribution of various factors to the growth of the US economy. When applied to air transportation, the MFP method decomposes the US airline industry’s output growth into two separate categories that include the change in output caused by the use of more inputs (e.g., more aircraft in the case of airlines) and the change in output caused by the improved utilization of such inputs. The latter (i.e., improved utilization of inputs) is what economists refer to as increased productivity (Oum et al., 1992). However, aggregate MFP measures do not clarify the extent to which output has increased due to changes in input or increased productivity of those inputs. By definition, an entity can improve its productivity in a variety of ways that include: increased output with constant input, output increased faster than input increased, decreased input with constant output, and so on. MFP estimates are computed by removing changes in factors of production from the change in output, relative to a base period. The remaining portion, or MFP residual, serves as a gross measure of productivity.

Increases in MFP are the result of increased output (i.e., ASMs, RPMs, or RTMs) over and above the gain due to the increase in inputs (i.e., fuel, labor, capital, and intermediate purchases). Therefore, aggregate measures of MFP include a broad range of influences and changes in MFP are the result of a combination of other factors such as:
• Economies of scale (increase size, increase output);

• Changes in the production process (e.g., single cabin versus multi-fare class structure);

• Industry changes (e.g., bankruptcies, mergers, and acquisitions);

• Operational attributes (e.g., increase stage length, load factors, block hours);

• Managerial skill (e.g., revenue management and yield strategies);

• New technology (e.g., fuel-efficient aircraft and use of info. technology); and

• Economic conditions (e.g., economic recessions, terrorist attacks).

4.2 MFP Methodology

This research applied the MFP methodology to generate aggregate measures of productivity in the US airline industry. To compute MFP measures, aggregate output and input information was collected on US passenger airlines. Outputs are expressed in physical quantities that include revenue-passenger miles (RPMS), available-seat miles (ASMs) and revenue-ton miles (RTMs). Inputs are expressed as value measures that include labor, fuel, capital, and intermediate expenses. Although inputs can be defined as either physical quantities (e.g., labor hours, gallons of fuel) or value (price) measures, we expressed inputs in constant dollars of expense to adjust for increased costs over time. Input prices were indexed (i.e., adjusted for the effect of inflation) from nominal to real values using US Consumer Price Index (CPI) measures published by the Bureau of Labor Statistics (BLS 2012). Refer to Chapter 3 Industry and Carrier Data for a detailed description of both output and input measures. Transport related costs (i.e., fees paid to regional partners, extra baggage, and otherwise miscellaneous overhead costs) result in no production of output and thus are excluded from all MFP calculations to not overstate their impact on MFP measures. Similar to Apostolides (2008), the MFP methodology applied in this thesis...
uses physical outputs and input prices to generate aggregate productivity measures (i.e., MFP residuals) expressed as:

\[
\frac{\Delta T}{T} = \frac{\Delta Q}{Q} - \left[ (\alpha \frac{\Delta \text{Labor}}{\text{Labor}}) + (\beta \frac{\Delta \text{Capital}}{\text{Capital}}) + (\gamma \frac{\Delta \text{Intermediate}}{\text{Intermediate}}) + (\delta \frac{\Delta \text{Fuel}}{\text{Fuel}}) \right] \tag{4.1}
\]

where:

\[
\frac{\Delta T}{T} = \text{growth of MFP;}
\]

\[
\frac{\Delta Q}{Q} = \text{growth of output includes RPMs, ASMs, RTMs;}
\]

\[
\frac{\Delta \text{Labor}}{\text{Labor}} = \text{growth of total labor and related expenses;}
\]

\[
\frac{\Delta \text{Capital}}{\text{Capital}} = \text{growth of total aircraft and non-aircraft expenses;}
\]

\[
\frac{\Delta \text{Intermediate}}{\text{Intermediate}} = \text{growth of intermediate expenses}
\]

\[
\frac{\Delta \text{Fuel}}{\text{Fuel}} = \text{growth of fuel expenses;}
\]

\[\alpha, \beta, \gamma, \delta = \text{shares of total operating expenses}\]

Note that the growth of inputs are weighted by \(\alpha, \beta, \) etc., which correspond to the respective share of each input in TOE. Assigning weights to each input captures the relative importance of each factor in output production. For instance, historically, labor expenses accounted for about a third of the airline industry’s TOE before declining to about 25% between 2005 and 2009 as the share of fuel expenses increased from an average of 15% (between 1978-2005) to about 25% in the same time period.

Using Equation 4.1 MFP measures are discussed in the following section.

### 4.3 MFP Results

With system-wide data collected from the DOT’s Form 41 database on physical output quantities and CPI-adjusted input prices, MFP measures were computed annually and cumulatively from 1978 to 2009. Furthermore, the US airline industry’s MFP performance is compared with labor and fuel single factor productivity measures. A
portion of the input expense data (i.e., intermediate services purchased) was missing from 1978 to 1989; however, these data had minimal impact on the analysis. Although the MFP methodology accounts for the combined effects of all inputs, the output component includes a single measure only (see Equation 4.1). Therefore, independent measures of MFP are differentiated in this chapter by the particular output assumed. For instance, MFP in terms of RPMs (or RPM productivity) refers to the relationship of RPMs as the single output measure to share-weighted inputs (i.e., each input cost weighted by respective share of total operating expenses). By computing multiple MFP measures based on different output metrics, we capture the extent to which productivity can be overstated, or vice versa, depending on the output measure selected. Periods of economic downturns can affect US airline’s traffic (RPMs) and network capacity (ASMs) differently, and thus generate dissimilar MFP measures.

4.3.1 Annual MFP Performance since 1978

From 1978 to 2009, annual MFP growth was positive over the majority of the analysis period. Figure 4-1 shows that, on average, annual growth of MFP in terms of RPMs, RTMs, and ASMs grew 2.6%, 2.2%, and 1.7%, respectively. Negative annual MFP growth in 1980 and 1981 can be explained by the decline in the demand for air travel as a result of the economic downturn. The extent to which the recessions in the early 1980s impacted airline traffic and network capacity is reflected in the difference in the decline of MFP in terms of RPMs and ASMs between 1979 and 1981.

As shown in Figure 4-2 from 1979 to 1981, both airline traffic and network capacity declined faster than share-weighted inputs and thus annual productivity decreased over the same time period (see Figure 4-1).

In addition to the 1980-82 recessions, a significant portion of the decrease in annual MFP that occurred during the early 1980s can be explained by the increase in fuel prices in 1979, as shown in Figure 4-3. Fuel cost per gallon nearly doubled in a three year span (1978-1981), which increased the industry’s total fuel expense an average of 50% each year within the same time period. The growth in airline traffic and network capacity during the mid-1980s led to improved productivity performance. Airlines
experienced their highest annual MFP growth out of the entire analysis period in the 1980s (see Figure 4-1). On average, MFP growth increased 6% from 1982 to 1989 compared to 3% from 1992 to 1999 (irrespective of output measure).

Although the highest annual growth of MFP occurred during the 1980s, the increase in airline traffic relative to capacity in the mid-1990s enabled annual RPM productivity to significantly increase relative to ASM productivity (see Figure 4-1). From 1995 to 2000, MFP in terms of RPMs increased an average of 2.4% per year while MFP in terms of ASMs increased 0.9%. Inputs accelerated faster than both airline traffic and network capacity in the late 1990s (see Figure 4-2). From 1999 to 2000, while airline traffic increased almost 5%, inputs increased from 3.2% in 1999 to 9.7% in 2000. A portion of this increase in share-weighted inputs from 1999 to 2000 can be explained by the 50% increase in fuel cost per gallon in the same time period (see Figure 4-3). Inputs such as labor and capital expenses were also increasing at a constant rate during the late 1990s as the airline industry continued to expand and
traffic increased.

At the turn of the 21st century, the US airline industry experienced decreases in annual MFP (below -4%) in both 2000 and 2001 (see Figure 4-1). The decline in annual MFP in the early 2000s was primarily due to the decline in airline traffic and network capacity at a faster rate than inputs as a result of the September 11th attacks and economic recession in the early 2000s (see Figure 4-2). After 2001, annual MFP growth improved, especially in terms of RPMs, as airline traffic improved an average of 4% per year from 2003 to 2009. In 2006, for the first time over the analysis period, annual RPM and ASM productivity growth moved in opposite directions with the slight increase in airline traffic relative to network capacity (see Figure 4-1).

As shown in Figure 4-1, unlike the 3% increase in annual RPM and ASM productivity that occurred during the 1980s and 1990s, MFP in terms of RPMs increased an average of just 0.1% per year and MFP in terms of ASMs decreased an average
of -1.2% per year from 2000 to 2009. Nevertheless, the sudden increase in per gallon fuel costs and economic downturns in the 2000s skew the minimal to negative annual MFP growth that occurred. As fuel cost per gallon spiked in 2008 in the midst of a deep recession, annual MFP growth plunged 12% from 2007 to 2008, the largest decline in MFP over the analysis period. Because the US airline industry was fairly cyclical during periods of economic downturns, annual MFP estimates were highly sensitive to fluctuations in the US economy. As a result of the sudden increase in per gallon fuel costs, the share-weighted input component used to compute MFP was highly susceptible to year-to-year increases. Therefore, cumulative changes in MFP are computed and discussed in the following section to illustrate the effects of year-to-year fluctuations on the US airline industry’s productivity performance relative to a base period (1978).
4.3.2 Cumulative MFP Performance since 1978

The US airline industry experienced remarkable cumulative MFP growth since 1978, as shown in Figure 4-4. The 17% decline in cumulative MFP during the early 1980s was a result of increased fuel costs and economic downturns. The Oil Crisis of 1979 led to a large increase in the fuel input variable from 1979 to 1980, while growth in airline traffic decreased 3% over the same time period. Despite the negative productivity growth that occurred during the early 1980s, cumulative MFP for each output measure (i.e., RPMs, ASMs, RTMs) improved at least 80% over the 1980 to 1990 time period.

As shown in Figure 4-5, US passenger airlines improved their ability to utilize capacity with an increase in average system-wide load factors (i.e., proportion of output consumed) that started in the early 1990s. From 1980 to 1990, airline traffic and network capacity increased at similar rates and thus average system load factors...
(RPMs divided by ASMs) remained stable around 60%. Yet, the accelerated growth in airline traffic relative to network capacity that started in the early 1990s improved average system load factors to 70% between 1995 and 2000 and this increase in airline traffic explains the gap in RPM and ASM cumulative productivity growth over the same time period (see Figure 4-4).

![Figure 4-5: System-wide US Airline Total Traffic and Capacity Since 1978](image)

As airline traffic improved after the Gulf War and recession during the early 1990s, RPM cumulative productivity growth increased another 80% from 1990 to 2000, similar to the acceleration in the 1980s (see Figure 4-4). US passenger airlines’ traffic nearly doubled from 1990 to 2000 and thus RPM cumulative productivity growth increased to their highest peak since 1978 at 153% in 2000 (see Figure 4-4). Likewise, ASM cumulative productivity growth peaked in 2000 (up 112%) with the increase in network capacity. For the first few decades of the analysis period, with the exception of economic downturns, cumulative MFP in the US airline industry accelerated rapidly before taking its first major plunge at the turn of the century.
(see Figure 4-4). Prior to 2000, the airline industry’s growth meant the use of more resources (e.g., more aircraft and more employees) that proved to be unsustainable. The following section explores the impact of input factors on MFP throughout the analysis period.

Although the rapid increase in the airline industry’s outputs overshadowed the acceleration of inputs for the majority of the analysis period, the impact of these inputs on MFP were highlighted in periods of reduced demand for air travel, especially in the 2000s. Figure 4-6 shows the 25% increase in system-wide gallons of fuel consumed for US passenger airlines from 1989 to 1990 coupled with only a 6% increase in airline traffic and capacity (see Figure 4-5). This increase in gallons of fuel consumed explain why MFP leveled off during the late 1980s (see Figure 4-4). In addition to the use of more fuel, total fuel expenses for carriers spiked with the sudden increase in per gallon fuel cost (see Figure 4-3) during the early 1990s. Labor and capital expenses accelerated at comparable rates to that of fuel expenses with the addition of employees and capital in the first few decades.

Figure 4-7 shows the relative contribution of each input to the combined input component used to compute MFP measures over the analysis period (see Equation 4.1). The combined input component refers to the CPI-adjusted change in each input expense (1978 base) weighted by its relative share of TOE. Total fuel expenses dominated the combined input component during periods of increased fuel costs that occurred in the 1980s and 2000s (see Figure 4-3). However, the contribution of both labor and capital expenses to the combined input component significantly increased during the late 1990s before they peaked in 2000. As a result, the reduction of these input factors were a major part of US passenger airlines’ cost-cutting strategies in the 2000s.

The decline in airline traffic from 2000 to 2001 led to more than a 20% reduction in cumulative MFP in terms of RPMs (see Figure 4-4). Yet, average system-wide load factors increased another 10% since the 1990s (70% to 80% average) as airline traffic recovered after the early 2000s relative to network capacity (see Figure 4-5). RPM cumulative productivity increased 43% from 2001 to 2004. Furthermore, from
2004 to 2009, cumulative MFP in terms of ASMs reduced 1% while cumulative MFP in terms of RPMs increased 18% (see Figure 4-4). Both RPM and ASM cumulative productivity drastically dipped in 2008, as a result of the late 2000s recession and spike in per gallon fuel prices (see Figure 4-3).

Although higher load factors are desirable, the amount of revenue generated per passenger is just as critical. A major portion of the improved airline traffic since 2000 came at the expense of lower passenger revenues. The US airline industry’s system-wide yield, the average amount of revenue earned per passenger mile (i.e., total passenger revenue per RPM), dropped 20% over the entire 1990 to 2000 period compared to a reduction of 20% in just three years from 2001 to 2004, as shown in Figure 4-8. This 20% reduction in system-wide yield meant a loss of over US $8 billion in passenger revenue in the early 2000s, as the US airline industry’s total passenger revenue went from approximately US $35 billion in 2000 down to US $27 billion in 2002.
In the early 2000s, US passenger airlines experienced their largest decline of system-wide yield since the early 1980s when carriers were still adjusting to deregulation. System-wide yield stabilized after the early 2000s before experiencing yet another slight dip. In 2009, average yield in the US airline industry reached its lowest point of the analysis period (1978-2009), 50% less revenue per passenger mile since 1978 (8.9 cents per RPM in 1978 versus 3.6 cents RPM in 2009). Thus, although the US airline industry’s cumulative MFP (irrelevant of output measure) reached its highest peak over the analysis period in the 2000s, these increases did not translate to increased financial performance (i.e., profitability) in the same time period.

4.3.3 Productivity, Unit Costs, and Profits Compared

In addition to production efficiency, financial performance is a function of airlines ability to price above costs while remaining cost competitive (i.e., minimize costs).
By improving productivity, US passenger airlines strive to produce the highest output (e.g., more RPMs) at the lowest expense, and thus reduce per unit costs. However, although lower unit costs improve the potential for higher profitability, it is by no means a guarantee. Presumably, assuming unit costs remain constant, the higher unit revenue the more profits retained.

Figure 4-9 shows that with the exception of economic downturns, as cumulative MFP increased (see Figure 4-4), US passenger airlines continued to reduce their unit cost expenses in real terms over the analysis period. However, passenger unit revenue (i.e., total passenger revenue divided by ASMs), a measure of revenue generated per increment of capacity, declined in real terms the majority of the analysis period similar to unit costs. Though not as drastic as the 1980s, US passenger airlines further reduced their per unit costs in response to increased pressures over the 2000 to 2009 period. At the same time, passenger revenue per ASM plunged in the early 2000s with the reduction in yield. Although US passenger airlines’ unit revenues may be
Figure 4-9: Passenger Revenue versus Cost per Available Seat Mile (1978 dollars) expressed in various ways, passenger unit revenues were compared in Figure 4-9 to remain consistent with the MFP methodology that accounts for physical quantities of output (i.e., passengers) and excludes revenue generated from other services. The impact of additional revenue streams on productivity is discussed in Chapter 5, *Total Factor Productivity of US Airlines*.

As shown in Figure 4-10, US passenger airlines were profitable during periods of increased productivity. The airline industry’s most profitable period occurred between 1995 and 2000. During this period, the industry broke even in regards to passenger revenue and cost per ASM alone (not including additional revenue streams) and RPM cumulative productivity increased rapidly (see Figure 4-4). However, profits were highly variable even in periods of strong MFP growth.

Despite their cyclical financial performance, US passenger airlines experienced impressive productivity growth over the analysis period. RPM and ASM cumulative productivity were 191% and 117% higher than 1978 levels, respectively, which indicates a tremendous increase in the industry’s aggregate productivity performance.
since deregulation. In addition, the increased gap in RPM and ASM cumulative productivity went from a mere 5% difference in 1980 to a 75% difference in 2009, reinforced by the unprecedented average system-wide load factors the US airline industry experienced in the 2000s. From 2000 to 2009, average load factors for the US airline industry were near 80% and RPM and ASM cumulative productivity were 38% and 6% above 2000 levels, respectively.

4.3.4 Single and Multifactor Productivity Comparison

To compare MFP performance of the US airline industry with common single factor measures, labor and fuel cumulative productivity measures were computed. That is, labor productivity defined as RPMs and ASMs per FTE (full-time equivalent employee) and fuel productivity defined as RPMs per gallons of fuel consumed. Figure 4-10 shows that since 1978, cumulative productivity for both single- and multi-factor estimates improved significantly over the analysis period. As previously discussed,
Figure 4-11: Multi- and Single-factor Productivity Performance

MFP is 191% higher, relative to 1978, with dips that coincide with US recessionary periods (early 1980s, early 1990s, early 2000s and late 2000s). Although at a lower rate, labor productivity increased similar to MFP during the 1980s and 1990s with slight dips during economic downturns. The increased pressure to reduce costs and the use of technology that replaced previously labor-intensive tasks such as reservations, check-ins, and ticket purchases explain the sharp increase in labor productivity that started in 2000. The 23% reduction in the industry’s workforce from 2000 to 2005 led to a 76% increase in labor productivity.

In regards to fuel productivity, with the exception of the 15% decrease during the early 1990s, fuel efficiency increased the majority of the 1978 to 2009 time period. The spike in gallons of fuel consumed (see Figure 4-6) and decline in the demand for air travel (see Figure 4-5) explain the dip in the early 1990s. Yet, after 2000, the rate of fuel productivity accelerated faster than the previous two decades up until the end of the analysis period (2009), 119% above its 1978 level. As with each measure of productivity (i.e., both multi- and single-factors), the tremendous improvement in
fuel productivity since 1978 is explained by a variety of factors that include capacity
discipline, advanced technology (e.g., fuel-efficient aircraft), and tremendous growth
in airline traffic, among others.

4.3.5 Limitations of MFP

The main drawbacks of using the MFP method to compute aggregate measures of
productivity are: 1) the inability to capture the effects of multiple outputs (e.g.,
cargo) on productivity and 2) the inability to identify specific factors that led to
productivity improvements. Because MFP cannot be measured directly, the residu-
als generated account for the effects of total output, not caused by primary inputs
(see Equation 4.1). Unlike both outputs and inputs, MFP is computed indirectly
and thus measures intangibles that can range from managerial and organizational
changes to the use of advanced technology. In addition, MFP measures are defined
as the relationship between a single output (e.g., RPMs) and combined inputs. The
MFP methodology does not encompass additional revenue generated by airlines, and
thus may understate productivity performance, or vice versa. Consequently, total
factor productivity (TFP), extends the MFP methodology by accounting for multiple
outputs and inputs of airlines, which enable accurate head-to-head comparisons of
productivity performance among US carriers. Details TFP measures for individual
carriers are discussed in Chapter 5.

MFP Conclusion

Irrespective of which measure of output is assumed, both cumulative and annual pro-
ductivity measures indicate that US passenger airlines experienced tremendous pro-
ductivity growth over the past 30 years. Both multifactor and single factor measures
of productivity more than doubled since deregulation (see Figure 4-11). Recessionary
periods and other external challenges (e.g., fuel spikes) coincide with reductions in
productivity. Despite the challenges that occurred after 2000, how did individual NLC
and LCC carriers perform in terms of improving productivity? Given these improve-
ments in the airline industry’s aggregate productivity, Chapter 5 computes measures of TFP to compare and explore the extent to which individual carriers improved their productivity between 1995 and 2010.
Chapter 5

Total Factor Productivity of US Passenger Airlines

The purpose of this chapter is to measure and compare total factor productivity (TFP) performance of US passenger airlines from 1995 to 2010 to explore changes in productivity and identify the underlying sources that help explain such changes. Because this chapter focused on total factor productivity, the terms TFP and productivity are used interchangeably. By examining changes in TFP from 1995 to 2010, we evaluated productivity performance of both US NLCs and LCCs during changes that occurred after 2000 that include the growth of LCCs, restructuring efforts of NLCs, and the impact of exogenous factors such as economic recessions and the attacks on September 11th.

To accomplish these objectives, we used a TFP model to compute annual productivity measures for individual carriers. TFP measures ignore specific sources of productivity, and therefore, we applied regression analysis to identify specific factors that can be attributed to observed productivity differentials. Data were collected from 1995 to 2010 period on individual US airlines from MIT’s Airline Data Project, which, in turn, was extracted from the Department of Transportation’s Bureau of Transportation Statistics Form 41 database (DOT 2011). Relevant data includes information on carriers’ traffic, operational attributes, and financial performance.

The following section discusses the methodology and data required to compute
measures of TFP. Then, computed measures of TFP are compared and discussed among three panel sets that include both NLCs and LCCs and a combined set. Lastly, we conclude with specific sources that help explain a portion of the observed TFP changes.

5.1 Total Factor Productivity

Total factor productivity is defined as the aggregate output produced per unit of aggregate input. Unlike aggregate measures of MFP computed in Chapter 4 *Multifactor Productivity in the Airline Industry*, TFP measures account for multiple revenue streams generated by US passenger airlines. That is, the improvements in an airline’s ability to generate additional revenues, such as cargo revenues, are included in the carrier’s output component. This distinction of a single output versus total output is the primary difference between MFP (used in Chapter 4) and TFP (Diewert and Nakamura, 2005). As stated in Andriulaitis, Frank, Oum, and Tretheway (1986), TFP is the most widely accepted means to compare productivity across firms, over time, or a combination of both (as cited in Windle (1991)). To compute TFP, detailed data of both quantity and value measures of a carrier’s output and input variables were required. The output and input variables were aggregated into separate output and input indexes using the *trans-log multilateral index procedure* proposed by Caves et al. (1982).

5.1.1 Methodology

The *trans-log multilateral index procedure* has a broad number of applications, one of which we applied in this thesis to compute TFP measures of US passenger airlines. Fundamentally, this index procedure is a weighted average that uses revenue and cost shares as weights when aggregating an entity’s outputs and inputs (Oum and Yu, 1995). By using revenue and cost shares as weights, shifts in the relative contribution of factors that change over time are reflected in the higher weights given to output variables with higher impacts (e.g., passenger service) and input variables with higher
costs (e.g., fuel consumed).

To compute productivity among US passenger airlines using the trans-log multilateral index procedure, separate multilateral output and input indices were computed and then combined to form a multilateral productivity index, which we refer to as TFP. To develop these individual output and input indexes, Caves et al. (1982) extended the Tornqvist-Theil-translog index, defined as:

\[
\ln T_{kl} = \frac{1}{2} \sum (S_{li} + S_{ki}) \times \ln \frac{Z_{ki}}{Z_{li}}
\]  

(5.1)

where the index \( T \) (i.e., output or input) of two entities (or time periods) \( k \) relative to \( l \) is defined as the value shares \( S \) of each entity’s component \( i \) multiplied by the change in the corresponding price or quantity \( Z \) of entity \( k \) relative to entity \( l \). However, to make multiple output, input, and productivity comparisons, this index was extended from bilateral to multilateral to enable what Caves et al. (1982) refer to as “transitive” comparisons (i.e., two or more entities). To be transitive, the indexes must satisfy an important feature known as the circulatory requirement, developed by Fisher (1922) (as cited in Caves et al. (1982)). The circulatory requirement ensures TFP measures are comparable regardless of the base selected (i.e., carrier or year) expressed as:

\[
I_{kl} = \frac{I_{km}}{I_{lm}} \quad \text{or} \quad \ln I_{kl} = \ln I_{km} - \ln I_{lm}
\]  

(5.2)

where the specified index \( I \) for entity \( k \) relative to entity \( l \) can be computed irrelevant of the base \( m \) selected. Note that \( I \) may represent the individual output or input indices as well as the overall productivity index.

Using Equation 5.1 to compare the proportional change in output of entity \( k \) relative to \( l \), represented as \( \delta_{kl} \), revenue shares \( R \) and the change in corresponding physical outputs or prices \( Y \) is expressed as:

\[
\ln \delta_{kl} = \frac{1}{2} \sum (R_{ki} + R_{li}) \times \ln \left( \frac{Y_{ki}}{Y_{li}} \right)
\]  

(5.3)
By adding a third carrier, say \( m \), results in three bilateral comparisons that in general will not satisfy the circulatory requirement from Equation 5.2. The output of entity \( k \) relative to the output of all \( S \) entities is defined as the geometric mean of the bilateral output comparisons between entity \( k \) and each of the entities \( S \). The geometric mean is defined as the average of the natural logs of a particular entity’s index values. Consequently, the multilateral output index, which enables output comparisons among multiple entities, is derived from the geometric mean and expressed as:

\[
\ln \delta^*_kl = \ln \bar{\delta}_k - \ln \bar{\delta}_l = \frac{1}{2} \left( \sum (R^k_i + \bar{R}_i) \ast \ln \left( \frac{Y^k_i}{Y_i} \right) - \sum (R^l_i + \bar{R}_i) \ast \ln \left( \frac{Y^l_i}{Y_i} \right) \right) \tag{5.4}
\]

where \( \bar{R} \) refers to the arithmetic average and \( \bar{Y} \) refers to the geometric mean. The primary difference between the bilateral and multilateral indexes is the replacement of the arithmetic average of the physical output \( Y_i \) used for two entities with the geometric mean of the physical output \( \bar{Y} \) across multiple entities.

Similar to the multilateral output index shown in Equation 5.4, the multilateral input index is derived to enable input comparisons among multiple entities. Analogous to \( \delta_k \) and \( \delta_l \), we denote \( \rho_k \) and \( \rho_l \) to represent the proportional changes in input of two entities \( k \) and \( l \). Input comparisons among multiple entities using cost shares \( W \) of input \( n \) in relating change in the physical quantity \( X \) of entity \( k \) relative to entity \( l \) is expressed as:

\[
\ln \rho^*_kl = \ln \bar{\rho}_k - \ln \bar{\rho}_l = \frac{1}{2} \left( \sum (W^k_n + \bar{W}_n) \ast \ln \left( \frac{X^k_n}{\bar{X}_n} \right) - \sum (W^l_n + \bar{W}_n) \ast \ln \left( \frac{X^l_n}{\bar{X}_n} \right) \right) \tag{5.5}
\]

where \( \bar{W} \) and \( \bar{X} \) represent the arithmetic mean and geometric mean, respectively.

Using the definition of TFP, Equation 5.4 and 5.5 are combined to form the multilateral productivity index used in this thesis to compute TFP for a single airline across multiple time periods, expressed as:

\[
\ln \lambda_{kl} = \ln \bar{\delta}_{kl} - \ln \bar{\rho}_{kl}
\]
\[ \ln \lambda_{kl} = \frac{1}{2} \sum (R^k_i + \bar{R}_i) \ast \ln \left( \frac{Y^k_i}{Y_i} \right) - \frac{1}{2} \sum (R^l_i + \bar{R}_i) \ast \ln \left( \frac{Y^l_i}{Y_i} \right) - \frac{1}{2} \sum (W^k_i + \bar{W}_i) \ast \ln \left( \frac{X^k_i}{X_i} \right) - \frac{1}{2} \sum (W^l_i + \bar{W}_i) \ast \ln \left( \frac{X^l_i}{X_i} \right) \] (5.6)

where the proportional productivity change of entity \( k \) relative to \( l \), denoted as \( \lambda_{kl} \), is computed by subtracting the proportional input change of entity \( k \) relative to \( l \), denoted as \( \rho_{kl} \), from the proportional output change of entity \( k \) relative to \( l \), denoted as \( \delta_{kl} \). Using log properties, TFP measures computed using Equation 5.6 can be rewritten as the multilateral output index divided by the multilateral input index.

Overall, both output and input indexes assume entities experience constant returns to scale and perfect competition (i.e., airlines maximize revenues conditional on input levels and output prices and minimize costs conditional on input prices and output levels). Although Caves et al. (1982) developed both output and input indexes that combine to compute TFP as cross-section comparisons (i.e., entity \( k \) versus entity \( l \)), the authors indicate, “they [indices] could just as well be time series comparisons or combined cross section, time series comparisons” (Caves et al., 1982, p.76). Thus, we computed annual TFP measures for each airline during the 1995 to 2010 period to compare productivity performance over time and between carriers. Using Equation 5.6, measures of TFP were computed based on a data set of US passenger airlines discussed in the following section.

### 5.1.2 US Airline Data

To measure TFP, we built a data set containing information on both NLCs’ and LCCs’ output and input variables from 1995 to 2010. The key statistics for the sample airlines are presented in Table 5.1, organized by carrier type (i.e., NLC or
Table 5.1: Key system-wide characteristics of US airlines in 1995 and 2010


<table>
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<tr>
<th>Airline</th>
<th>Total Revenue (US$ billions)</th>
<th>RPMs (millions)</th>
<th>% RPMs Int’L</th>
<th>No. of Employees (FTE)</th>
<th>Average Stage Length (miles)</th>
<th>Average Load Factor (%)</th>
<th>% Passenger revenue</th>
<th>% Freight revenue</th>
<th>% Incidental revenue</th>
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</tr>
</tbody>
</table>

Source: US DOT Form 41 via BTS; Schedule P10, Schedule P12, and Schedule T2

1excludes Transport Related Revenues
2includes both mail and cargo

LCC) and year (i.e., 1995 and 2010). As previously mentioned, transport related expenses and revenues are excluded from all calculations. Our data set includes US carriers that provided both domestic and international services with a significant focus on scheduled passenger services. Carriers primarily engaged in cargo or charter services were excluded.

There are large variations among carriers in regards to revenue, traffic, and other characteristics. In general, NLCs transported the majority of traffic (RPMs), thus generated on average more revenue than LCCs. The size of the airlines in the sample, measured by annual operating revenue, range from US $24 billion for Delta Airlines to just over US $1 billion for Frontier Airlines.

Note that output mix (i.e., % passenger revenue, freight revenue, etc.) for a particular airline may not sum to 100% due to rounding. Although carriers such as AirTran and Frontier Airlines date back to the mid-1990s, we focused on the carriers’
data from 2000 to 2010 due to information that was inconsistent or not reported prior to 2000. Also, because Northwest and America West Airlines did not exist in 2010, both carriers are excluded from that corresponding section of the table; however, both carriers’ TFP measures were computed and evaluated in this analysis for the periods each airline operated (i.e., Northwest from 1995-2009 and America West from 1995-2005).

Legacy carriers increased their international presence over the analysis period carrying on average over a third of their traffic internationally, as of 2010. With the exception of jetBlue, most of the LCCs focused on providing domestic service. From 1995 to 2010, NLCs such as Delta and Continental Airlines nearly doubled their international traffic and thus their average stage length (i.e., average distance flown per aircraft departure) significantly increased. Overall, with the increased emphasis on international traffic for NLCs, their stage lengths on average were longer than LCCs. However, LCCs such as jetBlue and Alaska Airlines had competitive stage lengths to take advantage of economies of distance (lower unit costs). Since 1995, average system load factors for all airlines increased to a historic high of 80%. Although NLCs on average had more employees relative to LCCs, their workforce significantly decreased over the analysis period.

5.1.3 The key factors of TFP: Outputs and Inputs

Details on specific outputs and inputs of US carriers were required to compute TFP measures. An airline’s outputs are defined as services produced that provide value to the overall production process (i.e., services that generate revenue) that include:

- Passenger revenue;
- Baggage fees;
- Cargo revenue;
- Cancellation fees; and
- Incidental (non-core activities) revenue.
Therefore, using similar approaches to those of Oum and Yu (1995) and Homsombat et al. (2010), data on prices and quantities for four categories of outputs were collected each year from 1995 to 2010 including: (1) scheduled revenue passenger-miles; (2) scheduled revenue ton-miles of freight; (3) scheduled revenue ton-miles of mail; and (4) incidental revenue. The incidental revenue category includes revenue (i.e., baggage, cancellation, and miscellaneous fees) that was not part of the airline’s core revenue streams (e.g., passenger or freight) and thus did not fit into any other output category. Each output’s respective revenue share was computed as a percentage of total operating revenue. With the exception of the incidental category, each output has a physical quantity (volume) measure. Details of the airlines’ output revenues and quantities are shown in Table 5.2.

Northwest and America West Airlines’ TFP measures were computed for both carriers from 1995 to 2009 and 1995 to 2005, respectively, and therefore data presented in the table include their last year of operation.

To include the incidental revenue category that may not be associated with a physical quantity, similar to past studies that use the TFP methodology proposed...
by Caves et al. (1982), we estimated an incidental quantity index weighted by its share of total operating revenue to directly include in the aggregate output index and serve as a proxy for the volume measure (i.e., physical quantity weighted by revenue share). To compute the index, CPI-adjusted incidental revenues were used to construct an annual quantity index weighted by their respective shares of total operating revenue. The incidental index described in Table 5.2 refers to the change in incidental revenues relative to American Airlines in 2010. For instance, the 1.13 value for Continental Airlines is interpreted as the incidental quantity index for Continental Airlines increased 13% higher from 2009 to 2010 relative to American Airlines' 2009 to 2010 value.

Similarly, inputs are defined as the resources used to produce output for an airline and thus accrue expenses that include:

- Labor;
- Capital;
- Fuel; and
- Materials.

Data were collected on prices and quantities for four categories of inputs including: (1) labor; (2) fuel; (3) capital; and (4) intermediate purchases. Similar to the incidental output category, the intermediate category includes all costs (i.e., materials, insurance, interest, outsourcing, etc.) that could not be categorized as labor, fuel, and capital. Details of each airlines’ expense and input information are presented in Table 5.3.

The labor category was constructed using full-time equivalent employees as the physical quantity weighted by the share of total operating expenses (TOE). The fuel category was constructed using gallons of fuel consumed weighted by the share of fuel cost in TOE. The capital category consists of total number of fleet weighted by the share of aircraft ownership costs in TOE. Aircraft ownership costs include rental and depreciation and amortization costs. It is important to note that previous
Table 5.3: Total Operating Expenses and Inputs for select US Carriers in 2010

Airline expenses and inputs, 2010 (Source: US DOT Form 41 via BTS; Schedule P10, P12, and T2)

<table>
<thead>
<tr>
<th></th>
<th>Labor (FTE)</th>
<th>Fuel (million gal)</th>
<th>Capital (total a/c)</th>
<th>Intermediate (index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>American</td>
<td>6,497</td>
<td>5,566</td>
<td>1,126</td>
<td>8,808</td>
</tr>
<tr>
<td>Continental</td>
<td>3,180</td>
<td>2,967</td>
<td>907</td>
<td>6,332</td>
</tr>
<tr>
<td>Delta</td>
<td>6,982</td>
<td>7,582</td>
<td>1,010</td>
<td>13,698</td>
</tr>
<tr>
<td>Northwest</td>
<td>2,732</td>
<td>2,386</td>
<td>491</td>
<td>4,773</td>
</tr>
<tr>
<td>United</td>
<td>13,447</td>
<td>4,418</td>
<td>775</td>
<td>8,763</td>
</tr>
<tr>
<td>US Airways</td>
<td>7,476</td>
<td>2,326</td>
<td>799</td>
<td>5,914</td>
</tr>
<tr>
<td>America West &amp; 743</td>
<td>771</td>
<td>358</td>
<td>1,646</td>
<td></td>
</tr>
<tr>
<td>Southwest</td>
<td>3,880</td>
<td>3,457</td>
<td>602</td>
<td>3,178</td>
</tr>
<tr>
<td>JetBlue</td>
<td>951</td>
<td>1,076</td>
<td>235</td>
<td>1,175</td>
</tr>
<tr>
<td>AirTran</td>
<td>573</td>
<td>819</td>
<td>275</td>
<td>823</td>
</tr>
<tr>
<td>Frontier</td>
<td>235</td>
<td>330</td>
<td>127</td>
<td>646</td>
</tr>
<tr>
<td>Alaska</td>
<td>889</td>
<td>726</td>
<td>207</td>
<td>1,149</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input Cost in US$ (million)</th>
<th>Input Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor (FTE)</td>
<td>Fuel (million gal)</td>
</tr>
<tr>
<td>American</td>
<td>65,506</td>
</tr>
<tr>
<td>Continental</td>
<td>37,760</td>
</tr>
<tr>
<td>Delta</td>
<td>76,742</td>
</tr>
<tr>
<td>Northwest</td>
<td>29,828</td>
</tr>
<tr>
<td>United</td>
<td>46,289</td>
</tr>
<tr>
<td>US Airways</td>
<td>30,876</td>
</tr>
<tr>
<td>America West</td>
<td>12,142</td>
</tr>
<tr>
<td>Southwest</td>
<td>35,089</td>
</tr>
<tr>
<td>JetBlue</td>
<td>11,211</td>
</tr>
<tr>
<td>AirTran</td>
<td>8,229</td>
</tr>
<tr>
<td>Frontier</td>
<td>4,309</td>
</tr>
<tr>
<td>Alaska</td>
<td>8,649</td>
</tr>
</tbody>
</table>

1 2009 data.
2 2005 data.
3 Intermediate Input Index normalized at American Airlines 2010

The literature constructed the capital category by weighting yearly lease prices of various aircraft types by the total number of aircraft per category of a particular carrier’s fleet, aggregated into a fleet quantity index. While this may improve the quality of the capital category, data on annual lease prices for specific aircraft were not readily available and can fluctuate depending on the source. By using total fleet and aircraft ownership costs, our capital category served as a first-order approximation that accounted for both leased and owned aircraft for a particular carrier.

Due to the inability to associate a particular quantity to the intermediate category, similar to the incidental output, an annual intermediate quantity index was constructed using CPI-adjusted intermediate costs weighted by their cost shares of TOE. The estimated quantity index is directly comparable over time and thus included in the multilateral input index of Equation 5.5.

To obtain a single measure that encompasses each output and input variable, using information reported in Table 5.2 and 5.3 aggregated output and input indices were constructed to compute TFP levels as the ratio of each carrier’s output index to its input index in a particular year. Using the trans-log multilateral index procedure
Table 5.4: Aggregated Output and Input indices for select US Carriers

Output and input indices for select periods (normalized at American Airlines 2000)

<table>
<thead>
<tr>
<th></th>
<th>Multilateral Output Index</th>
<th>Multilateral Input Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>American</td>
<td>0.88</td>
<td>1.00</td>
</tr>
<tr>
<td>Continental</td>
<td>0.61</td>
<td>1.07</td>
</tr>
<tr>
<td>Delta</td>
<td>0.86</td>
<td>1.09</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.92</td>
<td>1.15</td>
</tr>
<tr>
<td>United</td>
<td>1.00</td>
<td>1.14</td>
</tr>
<tr>
<td>US Airways</td>
<td>0.85</td>
<td>1.04</td>
</tr>
<tr>
<td>America West</td>
<td>0.75</td>
<td>1.06</td>
</tr>
<tr>
<td>Southwest</td>
<td>0.52</td>
<td>0.92</td>
</tr>
<tr>
<td>jetBlue</td>
<td>-</td>
<td>0.09</td>
</tr>
<tr>
<td>AirTran</td>
<td>-</td>
<td>0.44</td>
</tr>
<tr>
<td>Frontier</td>
<td>0.00</td>
<td>0.47</td>
</tr>
<tr>
<td>Alaska</td>
<td>0.66</td>
<td>0.89</td>
</tr>
</tbody>
</table>

* Average annual growth over the sample period (1995-2010)
1 2009 data.
2 2005 data.

(see Equation 5.6), Table 5.4 shows results of both aggregate output and input indices for select periods and their average annual growth rates, normalized at American Airlines' 2000 data. AirTran and jetBlue achieved the highest annual output growth of 49% and 16%, respectively, among carriers. However, jetBlue’s tremendous output growth is misleading due to the fact that it did not begin operations until 2000. Over the 2005 to 2010 period, jetBlue’s output increased an average of 10% per year. In addition, compared to NLCs, low-cost carriers’ inputs accelerated faster, such as both jetBlue and Frontier Airlines’ 27% and 9% annual input growth, respectively.

Continental and Delta led all NLCs in output growth accelerating an average of 6% annually over the analysis period, followed closely by US Airways 4% annual output growth. Although the output growth of NLCs such as United Airlines were stable, input growth decreased most likely because of the ability to reduce costs within bankruptcy protection (United Airlines filed for bankruptcy in 2002). The output and input indexes presented in the table provided the basis for calculating the index of TFP discussed in the following section.
5.2 Productivity Performance

TFP measures the amount of aggregate output produced by a unit of aggregate input and thus gives a comprehensive picture of an airline’s productivity. Using information from Table 5.4, TFP measures were computed by dividing the output index of particular carrier with its corresponding input index in the same year.

Table 5.5 shows gross TFP levels computed for each individual carrier and average annual growth rates over the analysis period (normalized at American Airlines’ 2000 level). Normalizing at American’s 2000 level was an arbitrary selection. As previously discussed, the transitive property yields similar TFP results regardless of the base year or carrier selected. For instance, to evaluate productivity of Southwest in 2000 relative to jetBlue in 2005, the corresponding values from Table 5.5 indicate Southwest’s productivity was 80% higher in 2000 relative to jetBlue’s productivity in 2005 (computed as 1.03 divided by 1.29). Due to unavailable or inconsistent data, LCCs such as AirTran and Frontier Airlines’ TFP measures were computed from 2000 to 2010. In addition, NLCs such as America West and Northwest’s TFP measures were computed up until their mergers (i.e., Delta-Northwest in 2008 and US Airways-America West in 2005). The following section compares TFP measures from Table 5.5 to examine productivity performance among carriers.

5.2.1 NLC Productivity Performance

Figure 5-1 shows that NLCs experienced a slight increase in TFP after 2005. Up until 2005, TFP was fairly stable with slight fluctuations that reflect both endogenous and exogenous factors that included bankruptcies, fuel increases, and economic downturns, among others. Continental Airlines led all NLCs with a 6% average increase in TFP over the 1995 to 2010 analysis period followed closely by US Airways with a 4% average TFP increase. Continental experienced its largest annual TFP increase of 44% from 2004 to 2005 and 20% from 2008 to 2009; however, both annual improvements were skewed by the negative affects that included a significant jump in total expenses in 2004 and the economic downturn in 2008.
Table 5.5: Total Factor Productivity for US Carriers 1995-2010 (American Airlines= 1.0)

Gross total factor productivity (normalized at American Airlines 2000 =1.0)

<table>
<thead>
<tr>
<th>Year</th>
<th>American</th>
<th>Continental</th>
<th>Delta</th>
<th>Northwest</th>
<th>United</th>
<th>US Airways</th>
<th>America West</th>
<th>Southwest</th>
<th>jetBlue</th>
<th>AirTran</th>
<th>Frontier</th>
<th>Alaska</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>0.97</td>
<td>0.75</td>
<td>0.91</td>
<td>0.99</td>
<td>1.03</td>
<td>0.86</td>
<td>0.93</td>
<td>0.78</td>
<td></td>
<td></td>
<td></td>
<td>0.86</td>
<td>0.90</td>
</tr>
<tr>
<td>1996</td>
<td>1.03</td>
<td>0.75</td>
<td>1.00</td>
<td>1.00</td>
<td>1.02</td>
<td>0.85</td>
<td>0.89</td>
<td>0.77</td>
<td></td>
<td></td>
<td></td>
<td>0.89</td>
<td>0.91</td>
</tr>
<tr>
<td>1997</td>
<td>0.98</td>
<td>0.84</td>
<td>1.04</td>
<td>1.05</td>
<td>1.05</td>
<td>0.87</td>
<td>1.04</td>
<td>0.80</td>
<td></td>
<td></td>
<td></td>
<td>0.90</td>
<td>0.95</td>
</tr>
<tr>
<td>1998</td>
<td>1.01</td>
<td>0.88</td>
<td>1.03</td>
<td>0.96</td>
<td>1.08</td>
<td>0.95</td>
<td>0.97</td>
<td>0.82</td>
<td></td>
<td></td>
<td></td>
<td>0.95</td>
<td>0.96</td>
</tr>
<tr>
<td>1999</td>
<td>0.98</td>
<td>0.98</td>
<td>1.04</td>
<td>1.06</td>
<td>1.04</td>
<td>0.90</td>
<td>1.01</td>
<td>0.91</td>
<td></td>
<td></td>
<td></td>
<td>0.94</td>
<td>0.99</td>
</tr>
<tr>
<td>2000</td>
<td>1.00</td>
<td>1.08</td>
<td>1.09</td>
<td>1.09</td>
<td>1.01</td>
<td>0.96</td>
<td>1.07</td>
<td>1.03</td>
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<td>0.66</td>
<td>0.70</td>
<td>0.91</td>
<td>0.92</td>
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<td>2001</td>
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<td>0.98</td>
<td>1.05</td>
<td>0.94</td>
<td>1.10</td>
<td>1.05</td>
<td>1.04</td>
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<td>0.67</td>
<td>0.65</td>
<td>0.88</td>
<td>0.90</td>
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<tr>
<td>2002</td>
<td>1.04</td>
<td>1.10</td>
<td>1.07</td>
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<td>1.06</td>
<td>1.34</td>
<td>1.03</td>
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<td>0.79</td>
<td>0.94</td>
<td>0.99</td>
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<td>0.91</td>
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<td>1.03</td>
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<td>2004</td>
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<td>1.06</td>
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<tr>
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<td>1.18</td>
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<td>1.23</td>
<td>1.37</td>
<td>1.31</td>
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<td>1.23</td>
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<td>2007</td>
<td>1.31</td>
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<td>1.21</td>
<td>1.26</td>
<td>1.23</td>
<td>1.49</td>
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<td>1.33</td>
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<td>1.39</td>
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</tr>
<tr>
<td>2009</td>
<td>1.50</td>
<td>1.64</td>
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<td>1.78</td>
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<td>1.22</td>
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<td></td>
<td>1.38</td>
</tr>
</tbody>
</table>

%chg*  2%  6%  3%  3%  1%  4%  2%  5%  15%  9%  7%  4%  3%

* Average annual TFP growth over the sample period (1995-2010)
US Airways experienced constant annual TFP growth (with the exception of the fuel spike in 2008) since 2005, despite falling into bankruptcy twice over the analysis period (2002 and 2005). This growth in TFP can be explained by the merger with America West in 2005 and therefore reflects the ability of carriers to improve overall efficiencies with industry changes (i.e., bankruptcies, mergers, acquisitions etc.). After America West increased its TFP 28% from 2001 to 2002, its productivity declined until its merger with US Airways in 2005. The ability to improve productivity through bankruptcy is supported by conclusions from both Homsombat et al. (2010) and Oum et al. (2005).

Productivity improvements did not come without down periods. Continental experienced the highest annual decline in TFP (down 29%) from 2003 to 2004 of all NLCs over the analysis period. This sharp decline can be attributed to the sudden increase in its input index, as shown in Figure 5-2. Continental’s input growth spiked in 2004, explained by a 40% increase in TOE from 2003 to 2004. However, since
2003, Continental improved its TFP by accelerating output growth and maintaining relatively stable growth of inputs. The annual 4% average increase in the output growth can be attributed to the 40% increase in Continental’s traffic from 2003 to 2010.

While improving output growth was a viable strategy to increase TFP for Continental, NLCs such as United Airlines used a more formal approach to reduce its cost structure and thus improve productivity, as shown in Figure 5-3. With the help of bankruptcy protection that started in 2002, United improved its TFP through the reduction of its input index throughout the 2000s. While United’s output index was fairly stable since 2002, its input index declined 20% from 2000 to 2010. The drastic decline in United’s input index in the early 2000s (25% from 2001 to 2002) can be explained by the 25% reduction in work force from just over 93,000 full-time equivalent employees in 2001 to just over 75,000 in 2002. The reduction of labor was a primary strategy of United to cut costs and improve efficiencies as the airline trimmed its work
force by 50% in the 2000s just before merging with Continental in 2010.

Despite the majority (5 out of 7) of the NLCs filed for bankruptcy protection over the analysis period, as of 2010, all NLCs have improved their productivity performance, especially in the latter portion of the 2000s. The disparity in TFP performance in 2010 range from legacy carriers who experienced the highest TFP levels such as Continental and US Airways 40% (above American Airlines 2000 level) to the lowest TFP levels of United Airlines with about 20% improvement (from American Airlines’ 2000 level). Although United Airlines was the least efficient in terms of TFP compared to the other NLCs in 2010, the ability to be productive by decreasing its input index may be viewed as a success.

5.2.2 LCC Productivity Performance

To compare TFP performance of low-cost carriers over the analysis period, Figure 5-4 shows TFP levels of each LCC normalized at Southwest Airlines’ 2000 level. Over-
all, LCCs experienced significant TFP growth over the analysis period, especially in the early 2000s. As of 2010, AirTran, Alaska, and Southwest Airlines were among

![Gross TFP Levels for LCCs (Normalized at Southwest Airlines 2000=1.0)](chart)

**Figure 5-4: Gross Total Factor Productivity of US LCCs**

the leading LCCs in terms of TFP performance nearly 50% higher than Southwest Airlines’ 2000 level. Prior to 2000, Alaska and Southwest’s TFP levels were fairly stable until the turn of the century when both carriers experienced unparalleled TFP growth relative to the 1995 to 2000 time period. Southwest improved TFP at a constant rate of 5% between 2003 and 2010. Throughout the analysis period, Frontier’s TFP performance was cyclical before declining after filing for bankruptcy protection in 2008.

From 2000 to 2004, jetBlue increased its TFP growth an average of 40% per year, enabled by its tremendous growth in traffic when it began operations. However, both jetBlue and Frontier’s annual TFP growth was positively skewed (median of just 4%) because of the significant TFP growth in the early 2000s. TFP growth for both airlines was fairly stable since 2005 as output stabilized and input growth continued
to increase. As of 2010, although jetBlue’s TFP was 33% higher, its TFP was about 20% below AirTran, Southwest, and Alaska Airlines’ TFP levels.

A large portion of the improvement in TFP for LCCs was fueled by the growth in airline traffic in the early 2000s. Although they carried a small portion of the US airline industry’s total output (international included), LCCs significantly improved their airline traffic share starting in the early 2000s. For instance, Figure 5-5 shows the improvement in TFP for AirTran explained by its output growth. As AirTran’s traffic stabilized in the latter 2000s, its output growth flattened in the same time period. However, the improvement in TFP for AirTran in the last few years of the analysis period (see Figure 5-4) is explained by the slight decline in input growth during the 2008 to 2010 period.

5.2.3 NLC and LCC Productivity Comparison

In regards to both NLC and LCC carriers, the majority of the airlines experienced a general improvement in TFP performance (at least 20%) over the analysis period.
While some carriers were negatively affected during economic downturns (2001 and 2008), carriers such as AirTran continued to improve its TFP performance in those same time periods. Through their increased traffic share, LCCs increased TFP levels tremendously in the early 2000s before leveling off in the latter portion of the decade. At the same time, the restructuring efforts by NLCs enabled them to increase their TFP to competitive levels. In terms of TFP, although LCCs such as AirTran and Southwest Airlines had a slight advantage in 2010, the TFP difference between NLC and LCC are not clearly evident as both Continental and US Airways achieved higher TFP levels than that of jetBlue and Frontier.

Aggregate productivity performance among NLCs, LCCs, and both carrier types combined are shown in Table 5.6. The annual TFP growth of both carrier types combined increased 4% per year over the analysis period. The highest annual TFP growth period for the combined set occurred in the early 2000s with an increase of 7% per year between 2000 and 2005. However, the majority of the annual TFP growth that occurred in the early 2000s can be attributed to the tremendous increase in TFP performance by LCCs.

TFP for LCCs increased an average of 15% per year between 2000 and 2005, compared to a 1% average increase for NLCs in the same time period. NLCs’ TFP increased an average of 2% over the entire analysis period. While LCCs witnessed tremendous growth in the early portion of the 2000s, as airline traffic declined, TFP followed increasing an average of 3% during the 2005 to 2010 period. Because TFP levels do not differentiate between sources of productivity changes among carriers, regression analysis was applied and discussed in the following section.
Table 5.6: Aggregate Annual Growth of Output, Input, and TFP for US NLCs and LCCs

<table>
<thead>
<tr>
<th>Year</th>
<th>Output</th>
<th>Input</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995-96</td>
<td>7%</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>1996-97</td>
<td>7%</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>1997-98</td>
<td>2%</td>
<td>2%</td>
<td>0%</td>
</tr>
<tr>
<td>1998-99</td>
<td>5%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>1999-00</td>
<td>6%</td>
<td>2%</td>
<td>4%</td>
</tr>
<tr>
<td>2000-01</td>
<td>-6%</td>
<td>-3%</td>
<td>-4%</td>
</tr>
<tr>
<td>2001-02</td>
<td>0%</td>
<td>-10%</td>
<td>10%</td>
</tr>
<tr>
<td>2002-03</td>
<td>-1%</td>
<td>1%</td>
<td>-2%</td>
</tr>
<tr>
<td>2003-04</td>
<td>7%</td>
<td>12%</td>
<td>-5%</td>
</tr>
<tr>
<td>2004-05</td>
<td>4%</td>
<td>-3%</td>
<td>7%</td>
</tr>
<tr>
<td>2005-06</td>
<td>10%</td>
<td>1%</td>
<td>9%</td>
</tr>
<tr>
<td>2006-07</td>
<td>1%</td>
<td>-2%</td>
<td>4%</td>
</tr>
<tr>
<td>2007-08</td>
<td>0%</td>
<td>6%</td>
<td>-6%</td>
</tr>
<tr>
<td>2008-09</td>
<td>-3%</td>
<td>-20%</td>
<td>16%</td>
</tr>
<tr>
<td>2009-10</td>
<td>9%</td>
<td>25%</td>
<td>-15%</td>
</tr>
</tbody>
</table>

1995-2000: 5%
2000-2005: 0%
2005-2010: 3%
1995-2010: 3%

1. Aggregate output measure computed as the average of each respective carrier's output index.
2. Aggregate input measure computed as the average of each respective carrier's input index.
3. Aggregate TFP measure computed as the average of each respective carrier's TFP index.
5.3 Sources of Observed Productivity Differentials

The primary objective of the regression analysis used in this thesis was to identify and explore the potential effects of specific factors on changes in TFP. Due to various factors such as network and market conditions that affect observed TFP levels beyond managerial control (as shown in Table 5.5), to decompose TFP differentials into specific sources, we estimated a set of log-linear TFP regressions on the following explanatory variables:

- Average load factor;
- Average stage length of flights; and
- Average block hours per day.

These factors are considered endogenous to the carrier, i.e., internal to the airlines and thus are considered “controllable”. On the contrary, studies such as Oum and Yu (1995) refer to network variables such as average stage length to be “uncontrollable” because it “depends on the route and market structure of an airline’s network”. However, in this thesis, average stage length and all other explanatory variables are regarded as controllable factors because US passenger airlines operate in a similar market structure in which carriers experience equal opportunity to access various markets and implement network changes. In addition, exogenous factors that may affect various aspects of the production function (e.g., fuel prices increase input and recessions decrease output) were estimated including carriers’ output composition and dummy variables for individual carriers, years, carrier type, and bankruptcy.

To develop our regression models, both the dependent and independent variables are transformed using the natural logarithm (except for dummy variables). The dependent variable (i.e., annual growth rate of TFP) is defined as the logarithm of the ratio of a particular carrier’s TFP levels in two consecutive years ($\ln\left(\frac{\text{TFP}_t}{\text{TFP}_{t-1}}\right)$). Similarly, the aforementioned explanatory variables are defined as annual growth rates. The specification of the general regression model with coefficients $\alpha$, $\beta$, $\delta$ and
error term $\varepsilon$ is expressed as:

$$
\ln TFP_i^t - \ln TFP_i^{t-1} = \alpha_0 + \beta_{ST} (\ln ST_i^t - \ln ST_i^{t-1}) \\
+ \beta_{LF} (\ln LF_i^t - \ln LF_i^{t-1}) \\
+ \beta_{BL} (\ln BL_i^t - \ln BL_i^{t-1}) \\
+ \varepsilon_{it}
$$

(5.7)

where the annual change in productivity $TFP_i$ for a carrier $i$ from year $t - 1$ to year $t$ is regressed on the corresponding annual growth of average stage length $ST_{it}$, average load factor $LF_{it}$, and block hours per day $BL_{it}$. A-priori expectations are an increasing relationship between dependent and independent variables. That is, ceteris paribus, higher productivity (TFP) growth is generally associated with higher growth of average stage length, load factors, and block hours per day.

To evaluate factors that affected observed TFP growth between NLC and LCC carrier types using Equation 5.7, regression analysis was applied to three separate panel sets described as:

- Panel Set 1 refers to all NLCs in our sample that existed from 1995 to 2010 (i.e., excludes Northwest and America West Airlines);

- Panel Set 2 refers to all LCCs in our sample that existed from 2000 to 2010; and

- Panel Set 3 refers to both NLCs and LCCs that existed from 2000 to 2010 (i.e., excludes Northwest and America West).

Note that for carriers such as Delta and Frontier Airlines that reported questionable data, analyses were carried out with and without both carriers and each regression output is discussed in the case results significantly differed. Furthermore, additional analyses were performed on panel sets that included both Northwest and America West and results were not disparate from those presented.
5.3.1 Regression Results

Using each panel set and a step-wise approach, we evaluated all possible subsets of explanatory variables. To select explanatory variables, variables that contained a-priori signs, regardless of significance, were retained in the regression output. Explanatory variables with counterintuitive signs that were insignificant were removed from each model. Lastly, for predictor variables significant with unexpected signs, further analyses were conducted to check for errors, data interaction, and omitted variables. As shown in Table 5.7, regression results of the TFP growth regressions for each panel set are summarized. Frontier and Delta are excluded from the regression output for NLCs and LCCs due to questionable data in regards to block hours per day information reported in MIT’s Airline Data project. To include both carriers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Panel Set 1</th>
<th>Panel Set 2</th>
<th>Panel Set 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.01 (0.55)</td>
<td>0.04 (0.01)</td>
<td>0.01 (0.65)</td>
</tr>
<tr>
<td>Ln (stage length)</td>
<td>N/A</td>
<td>1.07 (0)</td>
<td>0.16 (0.6)</td>
</tr>
<tr>
<td>Ln (load factor)</td>
<td>1.03 (0.07)</td>
<td>0.39 (0.39)</td>
<td>0.82 (0.03)</td>
</tr>
<tr>
<td>Ln (block hours)</td>
<td>0.38 (0.05)</td>
<td>0.18 (0.08)</td>
<td>0.25 (0.06)</td>
</tr>
<tr>
<td>LCC dummy</td>
<td>N/A</td>
<td>N/A</td>
<td>0.05 (0.05)</td>
</tr>
<tr>
<td>No. of Obs.</td>
<td>60</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.1</td>
<td>0.49</td>
<td>0.14</td>
</tr>
</tbody>
</table>

*P-values in parentheses

Panel Set 1: NLCs only from 1995-2010 (excludes DA, NW, and AW)
Panel Set 2: LCCs only from 2000-2010 (excludes Frontier)
Panel Set 3: NLCs and LCCs from 2000 to 2010 (excludes NW and AW)

All variables except dummies are in natural log
in the combined panel set and not overstate the effects of block hours per day on changes in TFP, questionable data was replaced (Delta 2004-2006 and Frontier 2002 and 2010) with the average of all other years.

The results from the growth regressions suggest the following four points:

- **Average stage Length** had positive coefficients for both Panel Set 2 (LCCs only) and 3 (NLCs and LCCs). The coefficient for LCCs was highly statistically significant, which indicates by increasing average stage length, on average, LCCs achieved higher TFP growth. The significance of longer stage lengths for LCCs can be explained by the 5% increase in stage lengths that occurred from 2000 to 2005 reflected by the early growth of LCCs. Since 2005, annual growth in average stage length for LCCs remained flat. Moderate evidence indicates improvements in the growth of average stage length had some effect on airlines ability to achieve higher productivity levels, irrespective of carrier type.

In regards to NLCs, minimal growth in average stage length over the analysis period explained their insignificant and counterintuitive coefficient. However, the pivot from domestic to more international traffic did improve the growth of average stage length for the majority of NLCs after 2000 and thus the effect of average stage length on TFP growth appear to be understated due to the lower growth (although higher than LCCs) over the analysis period.

- **Average load factors** had significant (with the exception of LCCs) positive coefficients for each panel set, indicating the growth in average load factors explained a significant portion of the growth in TFP over the analysis period. Both NLCs and LCCs average load factors grew to unprecedented levels in the 2000s where they stabilized around 80%. For LCCs, the coefficient is positive, however insignificant most likely due to the correlation between stage length and load factor (i.e., long-haul flights tend to have higher load factors relative to short-haul flights) and thus, the effect of both variables on TFP appear overstated for stage length and understated for load factors.

- **Block hours per day**, a measure of a carrier’s ability to utilize capital to improve
TFP, had moderate positive effects on the growth of TFP for all carriers during the analysis period. The higher coefficient for NLCs (significant at the 5% level) relative to the effect of block hours per day for LCCs implies that NLCs improvement in aircraft utilization, particularly after the early 2000s, explain a larger portion (relative to LCCs) of the improvements in TFP growth.

- **LCC dummy**, a measure of the two different carrier types, was significant (5% level) and had a positive coefficient (+0.05), which indicates, ceteris paribus, LCCs experienced on average 5% higher TFP growth relative to that of NLCs over the analysis period.

The R squared values for the majority of the models were less than 0.5, implying the majority of the changes in TFP over the analysis period are unexplained. Although we attained higher R squared values by including additional variables, explanatory variables were limited to the guidelines previously discussed to avoid overfitting. The results in this analysis are consistent to those of previous studies, such as Oum et al. (2005) and Homsombat et al. (2010). The unexplained portion, often referred to as technological progress, remain the largest and perhaps most important component of observed changes in TFP.

**Conclusion**

This chapter measured and compared TFP across US legacy and low-cost carriers from 1995 to 2010. The data set was first used to compute measures of TFP for individual airlines using the popular multilateral index procedure proposed by Caves et al. (1982). Then, TFP performance over the analysis period was compared among NLC, LCC, and both carrier types combined. Log-linear growth regressions were then estimated to explain the effects of network variables such as average stage length, load factor, and block hours per day on observed TFP growth. Although gross measures of TFP are affected by numerous factors, results illustrate how US carriers performed over the analysis period and thus provide key insights into the sources that help
explain such changes.

Overall, observed TFP growth for individual carriers over the analysis period were closely associated with output growth. AirTran and Continental both achieved significant output growth and thus higher TFP growth. During the 2000-2005 period, LCCs achieved considerably higher productivity growth relative to NLCs. TFP growth for the majority of the LCCs stabilized with traffic in the latter part of the 2000s. NLCs’ TFP growth increased an average of 2% over the analysis period, although TFP levels were competitive among LCCs as of 2010. Restructuring efforts of the NLCs resulted in productivity improvements in the latter portion of the 2000s.

Empirical evidence indicate a small portion of observed productivity levels were positively influenced by the low-cost carrier type and the increase in average stage length, load factors, and block hours per day. Specifically, the increase in system-wide average load factors to unprecedented levels were highly significant for both carrier-types combined and was reflected in the significant growth in productivity in terms of airline traffic relative to network capacity (as discussed in Chapter 4). Although TFP levels were comparable across carrier types, the regression analysis support our TFP results that suggest the LCC carrier types, on average, experienced slightly higher TFP growth over the analysis period.
6.1 Summary of Results

In this thesis, we measured and compared productivity at the aggregate US airline industry level from 1978 to 2009 and the individual US passenger airline level from 1995 to 2010. Specifically, we focused on comprehensive measures of productivity, opposed to traditional partial measures. To accomplish this, aggregate MFP measures were computed at the US airline industry level and disaggregate TFP measures were computed at the carrier level. The primary difference between the MFP and TFP methodologies is that the former accounts for a single output per combination of inputs while the latter accounts for total outputs and total inputs. Since TFP measures in general ignore specific sources of productivity, log-linear regressions were applied to identify the potential effects of network variables such as average stage length, passenger load factor, and block hours per day on TFP growth.

6.1.1 MFP Performance of the US Airline Industry

Through our analyses, we have shown that during the 1978 to 2009 period, US passenger airlines achieved tremendous productivity growth as cumulative MFP in terms of passenger miles (RPMs) and available seat miles (ASMs) increased 191% and 117%, respectively. MFP growth for US passenger airlines was primarily driven by the ac-
celear of both airline traffic and network capacity. It is clear that periods in which aggregate productivity declined were correlated with downturns in the economy, especially in the 2000s.

In the first decade after deregulation, cumulative MFP increased at least 80%, irrespective of output measure (i.e., RPMs, ASMs, or RTMs). With the exception of the recessions in the early 1980s, MFP in terms of passenger miles and available seat miles increased at similar rates for the remainder of the decade. Cumulative MFP leveled off in the late 1980s as a result of a sudden increase in fuel prices combined with rapid capacity expansion reflected in the 25% annual increase in gallons of fuel consumed from 1989 to 1990, their largest annual increase of the analysis period. While fuel prices retreated after their 1990 peak, MFP recovered slowly in the first few years of the 1990s with the negative effects of the Gulf War and economic downturn.

The second half of the 1990s proved to be one of the most successful periods for US passenger airlines in terms of both productivity and financial performance. The airline industry reported record profits during the 1995 to 2000 period, while MFP in terms of RPMs accelerated with airline traffic to its initial peak in 2000. Cumulative MFP in terms of RPMs and ASMs diverged as airline traffic nearly doubled from 1990 to 2000 and network capacity increased at a lower rate. MFP in terms of RPMs increased 80% in the 1990s before peaking in 2000, at 1.5 times its 1978 level. A large portion of this MFP increase in terms of passenger miles versus available seat miles can be attributed to technological improvements that include the use of revenue management, scheduling, and fleet assignment strategies.

Immediately following this profitable and productive period in the late 1990s, the turn of the century was a pivotal moment in which the largest decline in cumulative MFP occurred. For the first few decades of the analysis period, the airline industry continued to expand along with the addition of employees, increased aircraft rental costs, and expensive labor contracts (agreed to compensate for concessions in the early 1990s) and therefore, higher input costs. Until the turn of the century, the effects of these increases on aggregate productivity were masked by the tremendous growth in airline traffic. This rapid expansion quickly diminished as the consequences of
recessions, terrorist attacks on September 11\textsuperscript{th}, increase in fuel prices, and competition from LCCs that occurred in the 2000s all played key roles in the decline of both financial and productivity performance of legacy airlines in certain periods.

Cumulative MFP for US passenger airlines plunged with the decline in airline traffic in 2001 and fuel spikes of 2007-2008. As airline traffic improved after 2001, MFP in terms of RPMs surpassed its 2000 peak, closing out the analyses period 191\% above its 1978 level. Yet, as network capacity was removed, ASM productivity remained fairly stable in the 2000s, 117\% above its 1978 levels. Consequently, system-wide load factors increased to an average of 80\%, the highest over the analysis period.

In response to increasing input costs, volatile fuel prices, and the reduction in passenger revenues, legacy carriers increased their productivity and thus reduced their unit costs at the expense of employees and capacity cuts, to name a few. Across the industry, employees were reduced by over 20\% during the 2000 to 2005 period, which led to a dramatic improvement in labor productivity. Cumulative labor productivity in terms of RPMs and ASMs per FTE (full-time equivalent employee) increased 76\% and 51\%, respectively, between 2000 and 2005. Furthermore, aggregate labor productivity during this period was improved by the use of information technology to replace previous labor-intensive tasks and the growth of LCCs who in general had fewer employees.

Despite the MFP gains and unprecedented load factors that occurred in the 2000s, financial performance suffered as much of these improvements in airline traffic (RPMs) came at the expense of a drastic decline in average yields, and thus reduced passenger revenues. The 20\% reduction in system-wide yield in the early 2000s translated to a loss of US $8 billion in passenger revenue from 2000 to 2002 alone (DOT (2011)). The reduction in average yield to stimulate traffic was exacerbated by the double effect with the use of information technology for processing and ticket distribution. On one hand, carriers were able to process more passengers with fewer employees and thus improve labor productivity. On the other hand, the price transparency combined with the change in customers’ perceptions, especially business travelers, meant increased pressure for NLCs to match their lower priced counterparts and thus led to overall
lower fares. US passenger airlines were able to squeeze out just three years of profits in the 2000s, the fewest profitable years in a single decade during the analysis period.

6.1.2 TFP Performance of US Passenger Airlines

In regards to individual airlines productivity performance, TFP measures for both NLC and LCC carriers improved at least 20% over the 1995 to 2010 time period. US carriers increased their TFP an annual average of 4% over the analysis period. The highest annual growth of TFP for the combined set (NLCs and LCCs) occurred in the first half of the 2000s, explained in large part by LCCs rapid early growth.

Total factor productivity for legacy carriers increased an average of 2% per year over the 1995 to 2010 analysis period. The majority of NLCs’ TFP growth came in the latter portion of the 2000s, attributed to restructuring efforts. As of 2010, both Continental and US Airways led all NLCs in TFP and achieved the highest annual TFP growth (6% and 4% respectively). Avoiding bankruptcy protection within our analysis period, Continental and American improved their productivity by increasing output growth. On the contrary, the remaining NLCs studied improved productivity through a variety of cost-cutting strategies that enabled them to reduce their input index relative to outputs with the help of bankruptcy protection. For instance, after filing for bankruptcy twice (2002 and 2005), US Airways accelerated its TFP growth after its merger with America West in 2005. Similarly, while output growth was stable in the 2000s, United Airlines improved its TFP by reducing its workforce 50% in the same time period after filing for bankruptcy protection in 2002.

Low-cost carriers experienced significant productivity improvements over the analysis period as TFP increased 7% per year. Nevertheless, much of this TFP growth was skewed by the rapid growth of carriers such as jetBlue in the early 2000s. TFP growth for LCCs increased 15% per year between 2000 and 2005 compared to 3% between 2005 and 2010. In 2010, AirTran and Southwest, along with Alaska, led all carriers with near 50% higher TFP levels relative to 2000. Frontier and jetBlue’s TFP levels were the lowest of the studied LCCs with at least a 20% TFP gap in 2010.

As of 2010, although LCCs such as AirTran and Southwest experienced a slight
advantage, TFP levels were comparable between both NLC and LCC carrier types. Continental and US Airways TFP levels were higher than both jetBlue and Frontier in 2010. This implies that evidence of convergence in TFP levels exist among US passenger airlines, irrespective of carrier type. In addition, commonly used partial measures such as labor and aircraft productivity, used to differentiate between legacy and low-cost carriers, may be misleading in regards to discussions of overall productivity performance.

As expected, empirical evidence shows network variables alone explained a small portion of the changes in TFP over the analysis period. The poor R squared values imply that much of the change in TFP is “unexplained” and most likely attributed to measures difficult to quantify such as technological innovation and exogenous factors. However, since we were not concerned with making accurate predictions of future TFP, we focused on the potential effects of explanatory variables on observed change in TFP. The growth in TFP for LCCs can be explained by the growth in average stage length, load factor, and block hours per day. Average stage length for LCCs was highly significant and had the highest positive coefficient. The growth of load factors and block hours per day were significant in explaining the change in TFP for NLCs during our analysis period. For both carrier types combined, the growth of stage length, load factors, block hours per day, and the LCC carrier type (indicated by an LCC dummy variable) had all significant and positive coefficients, which implies a portion of the observed changes in TFP for all carriers studied were explained by these factors.

6.2 Conclusion and Future Research

The US passenger airline industry has made tremendous productivity improvements since deregulation. This implies that the increased competition and route and price freedoms were a success in terms of demanding improved efficiencies. Since 2000, the airline industry responded to challenges with cost-cutting strategies that included the reduction of labor, intermediate purchases (e.g., food, outsourcing, etc.), and capacity.
Nevertheless, a sustained profit has eluded the overall airline industry and thus begs the question, how important is productivity to the overall goal of sustained financial performance (profits)? This stark reality that increased productivity did not lead to higher profits implies the importance of other factors such as the carriers’ ability to price above costs and reduce input prices.

Profitability involves trade-offs between yield, productivity, and cost competitiveness. While unit costs for the overall US airline industry were briefly explored in Chapter 4, a true indicator of cost competitiveness compares unit costs among individual carriers with the effects of network characteristics difficult to control in the short term, such as average stage length, removed. In addition, what impact did cost-cutting strategies that removed excess network capacity and reduced in-flight services have on customers?

It is clear that deregulation of the US airline industry resulted in tremendous productivity improvements that were passed on to consumers in the form of lower fares. While we understand to what extent productivity improved since deregulation, the ability to sustain financial performance is critical. Future studies should assess productivity in tandem with cost competitiveness and yield performance to evaluate the trade-offs between each component. In addition, as carriers look to minimize costs, future studies should incorporate objective measures of service quality (e.g., dollars spent on in-flight services, on-time performance) that will provide more detailed empirical measures on the effects of these cost-cutting strategies.
Bibliography


