A Comparative Analysis of Cost Change for Low-Cost, Full-Service, and Other Carriers in the US Airline Industry

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Abstract

This study compares cost and productivity changes of full-service carriers (FSCs), low-cost carriers (LCCs) and 'other' carriers classified as regional or charter firms. Findings show cost reductions of 10 percent for FSCs and 20 percent for regionals/charters, and cost increases of 8.5 percent for LCCs from 1993 to 2014. Nontrivial productivity gains due to increases in load factor and stage length explain the findings for FSCs. Unexplained technical change accounts for the cost increases for LCCs, while productivity gains due to increases in load factor and stage length and unexplained technical change contribute to cost declines for 'other' carriers. These findings are interpreted as indicating (1) the LCC cost advantage over FSCs has eroded somewhat over this period, and (2) sources of cost changes over this period differ by air carrier classification.

I. Introduction

A substantial amount of research examines productivity growth following regulatory reform of the U.S. airline industry (See for instance, Oum and Yu, 1995 and Good, Nadiri, Roller and Sickles, 1993). Most of the findings from past research suggest that following regulatory reform airline companies in the U.S. experienced improvements in productivity. A contributing factor toward such growth has been the influence of low cost carriers (LCCs) on industry productivity.

Competitive pressure from LCCs has contributed to increased efficiency and the threat of bankruptcy for full-service (sometimes referred to as legacy) carriers. For instance, in the last 13 years, each of the three largest U.S. full-service carriers has declared bankruptcy. Tsoukalas, Belobaba, and Swelbar (2008) point out that bankruptcy and the threat of bankruptcy has allowed legacy (FSC) carriers to negotiate more favorable labor contracts, resulting in cost reductions. Moreover, they also suggest that increased labor seniority and slower growth have contributed to higher costs for LCCs. In fact, Tsoukalas, Belobaba, and Swelbar (2008) estimate that the average difference in labor cost per available seat mile between legacy carriers and low cost carriers decreased from 1.2 cents in 2000 to 0.3 cents in 2006. Further evidence of cost convergence between LCC and legacy carrier costs is presented by KPMG (2013), who in a global survey of airlines, find that average costs per available seat kilometer were 3.6 cents higher for legacy carriers than LCCs in 2006 and only 2.5 cents higher in 2011.

On the other hand, Borenstein (2011) argues that the cost difference between LCCs and legacy carriers has not converged in recent years, with costs adjusted for average flight distance remaining 40 percent higher for FSCs in comparison to LCCs over the last decade. Given the recent disagreement as to whether LCC and FSC costs are converging, and a lack of understanding on the reasons for LCC and FSC cost movement in recent years, this study explores recent cost changes for LCC and non-LCC carriers. Cost change is decomposed to identify productivity change from changes in density, firm size, movement characteristics, and technical change, and changes in input prices.

The remainder of this study consists of four additional sections. The next section examines various airline business models, and identifies factors that may contribute to varying productivity trends for LCCs, FSCs, and other carriers. Distinguishing the various airline business models is important, as major differences in business strategies among the various airline types have significant implications for costs and revenues. Section III describes the data construction and the empirical approach used to estimate cost functions for LCCs, FSCs, and the group of 'other' carriers consisting of regional and charter companies. Section IV presents cost findings for each carrier group, and concluding remarks are provided in section V.

II. Classifying the Airlines

While airlines employ a variety of strategies to control costs and to generate revenues, there are four basic types of carriers today, with carriers in each category employing similarities in the general business model employed (Leick and Wensveen, 2014). These include: (1) Full-Service Carriers (FSCs) – often referred to as network carriers or legacy carriers – providing frequent service using a hub and spoke network; (2) low-cost carriers (LCCs) providing point-to-point service, often using less congested secondary airports; (3) regional carriers (RCs) serving as feeders to the FSCs, and often not ticketing passengers; and (4) charter carriers (CCs) providing unscheduled service for vacation packages (Leick and Wensveen, 2014).

A. Full-Service Carriers (FSCs)

Although business models have been changing somewhat, the traditional full-service carrier is one that provides frequent service to a wide-variety of destinations, and provides a number of ancillary services, including complementary beverages, in-flight entertainment, airport lounges, and assigned seating (Huschelrath and Muller, 2012; Gillen, 2006; Leick and Wensveen, 2014). In essence, the FSC aims to be the one-stop air transportation provider to the communities it serves – providing air travel to business and vacation travelers to domestic and international destinations (often through alliances with international airlines).

Generally, travelers have a number of choices for flight times, and can arrive at many destinations without switching airlines. The major innovation that has enabled success of the FSC in providing service to a large number of origin-destination pairs, with frequent service has been the development of the hub-and-spoke system (Gillen, 2006; Bailey, 2002; Borenstein, 1992; Peteraf and Reed, 2008; Pels, 2008).

Gillen (2006) reports that some U.S. airlines had organized into hub-and-spoke networks prior to deregulation in 1978 (e.g. Delta). However, because regulation restricted route entry and exit, most airlines did not develop hub-and-spoke networks until after deregulation (Borenstein, 1992; Bailey, 2002; Gillen, 2006; Pels, 2008; Peteraf and Reed, 2008; Leick and Wensveen, 2014). Under a hub-and-spoke network, the carrier operates flights from smaller markets to a hub airport, timing arrivals close together so that passengers can then connect to flights from the hub to other markets. A major advantage of the hub-and-spoke system for the carrier is that it gives the carrier the ability to generate more traffic over light-density and high-density routes, and therefore to realize economies of density (Caves, Christensen, and Tretheway, 1984 show that airlines are characterized by economies of density). Carriers are able to use larger aircraft, to realize higher load factors (more passengers per available seat), and offer greater service frequency. Passengers benefit from the increased frequency of service and the wider array of destinations accessible without switching airlines.

As Borenstein (1992) points out, the benefits conferred to passengers from increased service frequency and an increase in the number of travel destinations, translate into market power for FSCs. Borenstein (1992) highlights the use of frequent flier programs (FFPs) (first introduced by American Airlines in 1981) to increase market power at hub airports. Since the hub carrier serves more routes from the hub airport than other carriers, it is easier for consumers to accumulate more frequent flier miles with that carrier. Furthermore, the benefit of obtaining frequent flier miles is more valuable on that carrier (as they have access to free trips to more destinations). This induces customer loyalty and results in increased pricing power – particularly for business trips (the highest yielding trips for the carrier). Because of a principal-agent problem, business travelers have an incentive to pursue travel on the carrier that generates the best frequent flier benefits, rather than on the carrier that charges the lowest fare (the company pays the airfare) (Borenstein, 1992).

In addition to being characterized by hub-and-spoke networks, another important characteristic of the FSCs is their use of complex yield management techniques. Yield management is another name for techniques used to maximize revenues. Strategies encompassed in yield management include overbooking, charging higher prices to customers with more inelastic demand (business travelers), and traffic management – or managing traffic to and from hubs to maximize revenues (Voneche, 2005). For the FSC, that offers refundable tickets, serves a large number of airports, and carries passengers together that are traveling to different destinations, this can be extremely complex.

Finally, as mentioned previously, the FSCs are often referred to as legacy carriers, as they were in existence prior to deregulation. While the term "legacy" is not as informative in terms of business strategy, it suggests an important characteristic that distinguishes these carriers from newer carriers – less flexible labor. These carriers existed during the less competitive era of regulation, when carrier resistance to union demands may have been reduced by the lack of competitive pressure (Hirsch and Macpherson, 2000). Although these carriers have been able to renegotiate labor contracts to increase the flexibility of labor, they continue to be plagued by work rules that create less flexible labor (see Bitzan and Peoples, 2014).

In summary, the FSCs can be characterized as offering a full range of services, operating with a hub-and-spoke network, operating a variety of plane sizes to accommodate different markets, and using yield management techniques to increase load factors and revenues. These carriers may also be plagued by less flexible labor and high union wages.

B. Low-Cost Carriers (LCCs)

A recently growing alternative model to the FSC model is the low-cost carrier model that focusses on no-frills, point-to-point service. Prior to deregulation, two U.S. airlines - Western Pacific and Southwest – operated point-to-point services in the deregulated intrastate markets of California and Texas, respectively (Bailey, 2002; Gillen and Gados, 2008). These carriers had fares that were 50 percent lower than those set by the CAB, and they were profitable (Bailey, 2002). Moreover, these served as a justification for deregulating the industry (Gillen and Gados, 2008). In one study, Keeler (1972) estimated an industry cost function, and then adjusted it to reflect the efficiencies of Western Pacific operating in California. He showed that regulated fares were between 20 and 95 percent above predicted unregulated fares in 1968.

Since deregulation, many new entrants have attempted to use a low-cost strategy – some successful and others not (Gillen and Gados, 2008). Like the FSC model, not all LCCs are alike. However, several common cost-reducing strategies have been employed by the most successful LCCs.

A number of authors suggest characteristics that enable LCC carriers to realize lower costs in comparison to the FSCs (Gillen, 2006; Button and Ison, 2008; Gillen and Gados, 2008; Pels, 2008; Pitfield, 2008; Huschelrath and Muller, 2012; Leick and Wensveen, 2014). These include: (1) operating a point-to-point network, allowing the carrier to realize savings in ground crew, maintenance, gates and other airport expenses from not having to accommodate a number of arrivals at approximately the same time to facilitate connections; (2) a uniform airline fleet, allowing the carrier to realize savings in buying parts, in maintenance, and in training costs (employees specialize in one type of aircraft); (3) serving smaller, secondary airports, where airport charges are often lower and where there is less congestion, resulting in faster turnaround of planes; (4) no-frills service or unbundling of services, including unreserved seating, no free food/beverages, no free baggage, no in-flight entertainment; (5) plane configurations that have more seats per plane and non-reclining seats, allowing the carrier to carry more passengers on a given flight; (6) simplified yield management, with fewer classes of passengers, resulting in savings in analytics; (7) using fewer employees per aircraft; and (8) using non-union labor. In addition, these carriers have used innovations to increase revenues. For example, in addition to selling the unbundled services, such as food and beverage, their websites often include options for hotel bookings and automobile rentals (Pitfield, 2008). Moreover, many don't use FFPs, as the advantage in terms of customer loyalty are not as big for these non-hub carriers.

As suggested by some of the strategies used by the LCCs to reduce costs (e.g. no-frills service, and more seats per plane), the LCCs may also be thought of as low-fare carriers. Gillen and Gados (2008) highlight the large number of entrants into the low-frills/low fare sector right after deregulation. However, as the authors state, the reason that many of these carriers were not successful is that they relied solely on a factor price advantage (through non-unionized labor), rather than using a new business strategy. Eventually, successful carriers copied many of the business practices of Southwest, and those carriers expanded the market for air travel (Gillen and

Gados, 2008). Gillen and Gados (2008) argue that after originally serving to get customers to travel that otherwise wouldn't, they now compete on many segments with the FSCs.

In summary, the LCCs can be characterized as offering no-frills service, operating with a point-to-point network, serving secondary airports, and employing a variety of techniques to achieve low-cost service (including achieving very high load factors). These carriers tend to charge lower fares, but often enhance those revenues by selling a variety of ancillary services.

C. Regional and Charter Carriers ('other carriers')

Regional carriers serve as feeders to the FSCs, serving small communities and transporting passengers to FSC hub airports. These carriers generally operate very small jets or turbo-prop airplanes, and typically offer one class of service (Leick and Wensveen, 2014). Moreover, they contract their capacity to the FSCs and do not sell their own tickets (ibid).

In many ways, the charter carriers are like the LCCs in that they employ similar strategies to reduce costs. Similar strategies include using few cabin staff, configuring planes to accommodate more seats, focusing on price sensitive customers, and various strategies to achieve a high load factor and high aircraft utilization (Pels, 2008). Unlike, LCCs, however, charter carriers do not provide scheduled service. The number of charter carriers has decreased since deregulation due to increased pricing freedoms given to established carriers (Gillen, 2006). Most charter airlines are involved in all-inclusive vacations now (Leick and Wensveen, 2014).

D. Comparing the Underlying Cost-Influencing Differences Between LCCs, FSCs and other carriers

As mentioned in the previous section, LCCs and FSCs use a variety of strategies to achieve low costs and high revenues. However, the obvious question that might be asked is: how these differences translate into measureable variables?

A variety of factors may contribute to a cost advantage for FSCs. Larger plane sizes, higher load factors, and increased service frequency are all benefits of the hub-and-spoke configuration used by FSCs. Chopra and Lisiak (2007) in examining FSCs and LCCs between 1994 and 2004, find that the average load factor is higher for FSCs in every year except 1994. They suggest that this advantage is likely to persist due to the nature of hub-and-spoke operations. The advantages of larger plane sizes and service frequency are likely to show up as higher traffic densities for the FSC carrier. This FSC cost advantage is especially prevalent when comparing operations of this carrier group with the regional companies serving small communities due to the low population densities of these locations. FSCs are likely to also experience a cost advantage over charter carriers, because this group of 'other carriers' are characterized as small companies that do not benefit from the economies of size associated with FSC operations.

Chopra and Lisiak (2007) also find that stage length is consistently higher for FSCs in comparison to LCCs throughout the 1994-2004 period. This advantage is largely due to flying internationally (Chopra and Lisiak, 2007).

LCCs also have a variety of factors contributing to cost advantages. The point-to-point network allows for savings in ground crew, gates, maintenance, and other airport expenses due to flights being more spread out. Chopra and Lisiak (2007) show that LCCs consistently utilized less employees per available seat mile in comparison to FSCs between 1994 and 2004. They also find that the rate of pay per employee is consistently less for LCCs over this period, but suggest that this advantage may not be sustainable. Chopra and Lisiak say this difference is due to differences in pension and insurance benefits – and that these benefits are being renegotiated by FSCs.

Other LCC cost advantages are likely to show up in lower aircraft maintenance and training expenses from using a uniform fleet, lower airport charges and faster turnaround from serving secondary airports, less ancillary costs from no-frills services, more passengers per plane due to tighter seating configuration, and less need to manage complex yield management systems. Chopra and Lisiak (2007) show that block hours (hours between aircraft departure and arrival) per plane are consistently higher for LCCs than FSCs between 1994 and 2004, supporting the idea of a faster turnaround due to serving secondary airports. While investigating each of these individual items is beyond the scope of our study, it is important to keep in mind that there are reasons to suspect cost advantages to each type of carrier for different reasons.

E. A Convergence Between LCCs and FSCs?

A number of authors point to increased competition between LCCs and FSCs in recent years. For example, using slightly different carrier definitions, Leick and Wensveen (2014) find that LCC share of U.S. traffic increased from 16 percent in 2000 to 25 percent in 2007, while Huschelrath and Muller (2012) find that LCC share increased from about 10 percent in 1995 to about 32 percent in 2009.

At the same time, the fare premium charged by FSCs above the LCCs has eroded. Huschelrath and Muller (2012) find that the percent of the top 1000 U.S. routes (in terms of traffic) served by both FSCs and LCCs increased from 10 percent in 1995 to 31 percent in 2009, while the percent of the top 100 U.S. routes served by both increased from 26 percent in 1995 to 64 percent in 2009. At the same time, they find a significant reduction in the fare premium charged by FSCs in comparison to LCCs. Borenstein (2011), states that LCCs compete with FSCs on more than 60 percent of all routes, and that LCC market share has increased from 10 percent in 1994 to 24 percent in 2009. Further, he finds that at the same time, the price premium charged by FSCs over LCCs has eroded. In particular, he estimates that the fare premium has decreased from over 90 percent in the early 1990s to over 30 percent in 2009. (Borenstein, 2011).

As a result of this increased competition between FSC and LCC carriers, there has been some reconfiguration of FSC and LCC operations. Borenstein (2011) points to an expansion of FSC networks by mergers and alliances. Since 2000, mergers of FSCs in the U.S. have included those between American Airlines and TWA, America West and U.S. Airways, Delta and Northwest, United and Continental, and U.S. Airways and American Airlines. A number of "Open Skies" agreements aimed at opening up international airline markets have also allowed U.S. carriers to enter into alliances with international carriers, cooperating on fares, marketing, and capacity with antitrust immunity (Leick and Wensveen, 2014). Since the first alliance between Northwest and

KLM in the early 1990s, a number of alliances have been formed, creating three large global alliances (Leick and Wensveen, 2014).

In addition to pursuing mergers and alliances, FSCs have adopted some LCC strategies, including less complicated yield management, unbundling services (e.g. baggage fees), improving aircraft utilization, and providing point-to-point service when there is enough demand (Leick and Wensveen, 2014). Moreover, some FSCs have gone so far as to create an LCC division within their own FSC. However, this has not been very successful in the U.S. (Gillen and Gados, 2008). Gillen and Gados (2008) point out that it has been difficult for FSCs to achieve the efficiencies of a low cost airline within their LCC divisions, due to a perception that the LCC division was the same as the parent company and due to union resistance to a large portion of FSC operations being run like a LCC.

At the same time, some LCCs have started to use some of the business practices used by the FSCs (Leick and Wensveen, 2014). These practices have included: some use of hubs or focus cities, selling tickets using the same methods as the FSCs, more frills (e.g. in-flight entertainment and assigned seating), premium class service, frequent flier programs, codesharing agreements, and multiple types of aircraft (Leick and Wensveen, 2014). Moreover, as noted by Mason and Morrison (2008), there is no homogeneous LCC strategy. Some LCCs have pursued various elements of the FSC strategy from the beginning.

Nonetheless, the increasing competition between LCC and FSC carriers, along with some converging of business practices may suggest a convergence in costs between the two. Tsoukalas, Belobaba, and Swelbar (2008) find a significant convergence between FSC and LCC unit costs during the 2001 through 2006 period. They find that the most significant convergence in unit costs is in labor costs. The authors suggest that FSC bankruptcies and the threat of bankruptcies has allowed them to restructure labor contracts with more flexible work rules and lower pay. At the same time, an increase in the seniority of LCC workers and slower growth has caused an increase in LCC labor expenses (Tsoukala, Belobaba, and Swelbar, 2008).

On the other hand, Borenstein (2011) and Huschelrath and Muller (2012) suggest that there has not been such a convergence in costs between the FSCs and LCCs. Borenstein (2011) finds that FSC unit costs have been between 30 percent and 60 percent higher than the LCCs throughout most of deregulation, and that they averaged 40 percent higher between 2001 and 2011 (with no signs of convergence). Huschelrath and Muller (2012) find that LCCs have either maintained or increased their cost advantage over this period. They find that cost per available seat mile was 8 cents for LCCs and 9.2 cents for FSCs in 1995, while it was 9.2 cents for LCCs and 11.4 cents for FSCs in 2009. When excluding fuel costs, they find that LCC cost per available seat mile drops from 7.48 cents in 1995 to 6.6 cents in 2009, while it increases from 8.4 cents to 11.1 cents for the FSCs.

These conflicting findings suggest that recent cost changes for FSC and LCC carriers are not well understood. In this study, we examine cost changes between 1993 and 2014 resulting from productivity changes and from changes in input prices for three subsets of air carriers: FSCs, LCCs, and a combination of regional and charter carriers (classified as ‘other carriers’). The next section of the study provides a brief description of the data used and the sample of airlines included.

III. Data and Empirical Approach

Data

To test for differences in productivity trends by carrier type this study uses individual airline Form 41 financial reports and T-100 traffic data reported by large certificated U.S. air carriers to the U.S. Department of Transportation for the years 1993-2014. After excluding information on cargo carriers, the raw data set is an unbalanced panel of 638 observations for 61 carriers.[1] Information taken from these reports are used to calculate total cost and determinants of cost for airline companies. These determinants include the prices of labor, fuel, capital and all other inputs; as well as an airline's average stage length, total ton miles and the percent of ton-miles that are freight ton-miles[2], number of airports served by the airline and the airline's average load factor.[3] An important benefit derived using these data sources is the sample population is large enough to allow separate cost and productivity analyses of full service carriers, low cost carriers and other carriers.

Descriptive statistics on airline companies' cost determinants are reported in Table 1. While these descriptive statistics provide a useful overview of cost determinants, additional insight into differences between the different groups of airlines and productivity changes within each group might be obtained by examining individual characteristics within each group in 1993 and in 2014.

Tables 2, 3, and 4 show a variety of statistics for FSCs, LCCs, and 'other carriers' in 1993.[4] As the tables show, FSCs and 'other carriers' realize average costs per available seat-mile that are 34 and 40 percent higher than LCCs, respectively. When comparing average costs per ton-mile, FSCs and 'other carriers' realize cost disadvantages of 28 percent and 46 percent, respectively.

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[1] The unbalanced panel occurs in part because of airline foreclosures, new carrier entry and airline mergers. Eighty observations were deleted due to missing variables, freight percentages of ton miles exceeding 50 percent, or unreasonably low fuel costs per gallon (less than $0.40).

[2] Bureau of Transportation Statistics compiles total ton-miles that include passengers and freight. Passenger miles are converted to ton-miles by multiplying them by .1 (Bureau of Transportation Statistics) and added to freight ton-miles. Although it would be desirable to estimate a cost function that includes both types of outputs, the simple correlation between the two is .907. This suggests severe collinearity problems would occur from the inclusion of both outputs in a cost function.

[3] Definitions and specification of the method used to compute cost determinants are presented in Table A1 of the appendix.

[4] In these tables, averages for cost per avail-seat mile are weighted by available seat miles; averages for cost per ton-mile, average load factor, average stage length, airports, labor share, and fuel share are all weighted by ton-miles; average density is weighted by the number of airports; and average available seat miles per employee is weighted by the number of employees. Weighted averages are preferred to simple averages, as there have been significant changes in the numbers of carriers in each group over time. The weighted averages provide a more accurate depiction of carrier characteristics by taking into account large companies' disproportionate share of industry activity. LCCs are identified based on a list from the International Civil Aviation Organization of the United Nations: http://www.icao.int/sustainability/Documents/LCC-List.pdf.

LCCs have average load factors that exceed those of FSC and other carriers by 10 and 7.5 percent, respectively. LCCs also show higher average stage lengths in comparison to FSCs and ‘other carriers’, by about 15 percent and 93 percent, respectively.

In comparing traffic densities (ton-miles per airport) between the various carriers, it is apparent the FSCs operate at much higher traffic densities in comparison to the other two – as expected, given the nature of hub-and-spoke operations. FSC traffic densities are more than 890 percent and 530 percent higher than LCCs and ‘other carriers’, respectively. This suggests that FSCs are likely to realize a cost advantage from economies of density. The number of airports served are also much higher for the FSCs, as expected.

On the other hand, available seat miles per employee are much higher from the LCCs in comparison to the FSCs and ‘other carriers’. This reflects various advantages in the LCC business model – e.g. the point-to-point network used by LCCs requires less ground crew and maintenance due to more spread out flights; serving smaller airports facilitates faster turnaround of planes; LCCs use tighter seat configurations; etc.

Finally, average labor share is higher for FSCs in comparison to LCCs and ‘other carriers’, potentially reflecting less flexible work rules and higher pay. Labor accounts for an average of 34 percent of FSC costs, in comparison to 28 percent and 27 percent for LCCs and ‘other carriers’, respectively.

Tables 5, 6, and 7 show these same statistics for FSCs, LCCs, and ‘other carriers’ in 2014. As the tables show, although the LCCs still enjoy a cost advantage over FSCs, the magnitude of the cost advantage is smaller. Moreover, ‘other carrier’ costs per ton-mile are smaller than those of the LCCs. In comparing cost per ton-mile between the three carrier types, FSC costs are 20 percent higher than LCCs, while “other” carrier costs are 7 percent lower than LCCs in 2014.

These simple comparisons support the idea that costs have converged among the various carrier types. For FSCs, this likely reflects big increases in average load factor, average stage length, traffic density, and available seat miles per employee. Moreover, the tables also provide some evidence that renegotiating labor contracts may also have had an influence, as labor accounted for an average of 34 percent of FSC costs in 1993 and only 24 percent in 2014.

‘Other carriers’ also realized big increases in load factors, stage lengths, and seat miles per employee from 1993 to 2014. This also is consistent with the reductions in costs that have occurred.

A useful visualization of changes in airline costs for the three carrier types is presented in Figure-1. This figure contains annual changes in average cost per ton-mile weighted by total ton miles for the three categories of air carriers. For the initial observation year in 1993, the average cost for FSCs and ‘other carriers’ are 28 and 46 percent higher than the average cost of LCCs, respectively. The LCC average cost advantage over FSCs erodes by 1997; however, the LCC-FSC average cost gap widens following that year and maintains an LCC cost advantage above 15 percent from 2001 to 2012. After a decline to a 11 percent advantage in 2013, LCCs achieve a cost advantage of about 20 percent in 2014. In contrast to the LCC-FSC average cost gap pattern of a declining then increasing gap, the average cost advantage of LCCs over other carriers remains large (in excess of 25 percent) until a large drop in the cost advantage starting in 2011. By 2013, the cost advantage belongs to the 'other' carriers in comparison to LCCs. In sum, cost findings for FSCs and 'other' carriers compared to LCCs supports cost convergence. Moreover, the period of increased divergence between 2001 and 2012 supports findings of previous studies that didn't find convergence. Although previous studies have not focused on regional and charter carriers, it is especially interesting that this group – thought to consist of a group of companies whose operating characteristics are unlikely to promote cost savings – has achieved such large cost reductions over this period (particularly since 2010). While these findings provide interesting insight on relative costs for the three airline categories, a more complete analysis requires cost estimation that allows distinguishing the separate cost and productivity effects of the cost determinants presented in Table-1.

Empirical Approach

The generalized cost function used to decompose productivity changes includes four factor prices, output, four technological characteristics and a time trend, and is specified as follows:

$$C = C(P_l, P_f, P_k, P_o, Q, FreightPct, LOAD, Stg\ Length, Pts\ Served, T)$$

where C denotes total cost. The four factor input prices are, P_L the price of labor, P_f the price of fuel price, P_k the price of capital and P_o the unit price of all other inputs. Output is defined as total ton-miles of passengers and freight carried.[5] Technological variables included in the cost function are the percent of ton-miles accounted for by freight, average load factor, stage length and number of airports served by an air carrier. The percent of ton-miles accounted for by freight is included to account for traffic mix. Load factor is defined as revenue passenger miles divided by available passenger miles. This variable is included to take into account the fact that many costs of operating a flight (e.g., flight crew, maintenance, fuel) do not increase proportionally with the number of passengers and tons on a flight. Average stage length, or the average segment length, refers to the length of the average flight of a particular airline. This variable is included to account for the fact that many costs are a function of the number of takeoffs or landings (e.g., maintenance, fueling, boarding, security, landing fees) and do not vary proportionally with distance. The number of points served is included as a proxy for firm size. Finally, we include firm fixed effects (i.e. firm dummy variables, including merger variables) variables to account for unmeasured firm characteristics, and a time trend to account for technical change.

The above cost function is then specified using second order Taylor series approximation around the mean. The expansion is simplified by taking the natural logarithms on both sides of the

[5] As mentioned previously, passenger miles are converted to ton-miles by multiplying them by .1 (Bureau of Transportation Statistics). The correlation between passenger miles and freight ton-miles is .907 in the sample, suggesting severe collinearity problems with using separate outputs.

equations and replacing partial derivative with parameters to give the translog specification shown in the following equation:

$$lnC = \alpha_0 + \sum_i \alpha_i ln\left(\frac{P_i}{\bar{P_i}}\right) + \beta ln\left(\frac{Q}{\bar{Q}}\right) + \sum_m \sigma_m ln\left(\frac{a_m}{\bar{a_m}}\right) + \theta T$$

$$+\frac{1}{2}\sum_i \sum_j \alpha_{ij} ln\left(\frac{P_i}{\bar{P_i}}\right) ln\left(\frac{P_j}{\bar{P_j}}\right) + \sum_i \tau_i ln\left(\frac{P_i}{\bar{P_i}}\right) ln\left(\frac{Q}{\bar{Q}}\right) \quad + \sum_i \sum_m \vartheta_{im} ln\left(\frac{P_i}{\bar{P_i}}\right) ln\left(\frac{a_m}{\bar{a_m}}\right)$$

$$+\sum_i \partial_i ln\left(\frac{P_i}{\bar{P_i}}\right) T + \phi \frac{1}{2} ln\left(\frac{Q}{\bar{Q}}\right)^2 + \sum_m \varphi_m ln\left(\frac{Q}{\bar{Q}}\right) ln\left(\frac{a_m}{\bar{a_m}}\right)$$

$$+\pi ln\left(\frac{Q}{\bar{Q}}\right) T + \frac{1}{2}\sum_m \sum_n \sigma_{mn} ln\left(\frac{a_m}{\bar{a_m}}\right) ln\left(\frac{a_n}{\bar{a_n}}\right) + \sum_m \mu_m ln\left(\frac{a_m}{\bar{a_m}}\right) t + \frac{1}{2}\gamma T^2 + \epsilon \qquad (1)$$

Where the symbols *P*, *Q*, and a are vectors containing the variables depicting input prices, output and technical characteristics, respectively. Using the translog specification also allows for obtaining input share equations shown below by taking the derivative of the cost equation with respect to input prices and applying Shephard’s Lemma.

$$\frac{\partial lnC}{\partial lnP_i} = \frac{x_i P_i}{C} = \alpha_i + \sum_j \alpha_{ij}\left(\frac{P_j}{\bar{P_j}}\right) + \tau_i ln\left(\frac{Q}{\bar{Q}}\right) + \sum_m \vartheta_{im} ln\left(\frac{a_m}{\bar{a_m}}\right) + \partial_i t + \epsilon \qquad (2)$$

where $\alpha_{i=1}, \alpha_{i=2}, \alpha_{i=3}, and\ \alpha_{i=4}$ represent labor, fuel, capital and other inputs’ share of total cost at the mean, respectively, and x_i represents the amount of input i used. This system of equations (the cost function and input share functions) is estimated within a seemingly unrelated system with one of the input share equations excluded to avoid perfect collinearity. Last, the necessary and sufficient homogeneity and symmetry conditions to construct a cost function that is linearly homogenous in factor input prices are imposed as follows using the following constraints:

$$\sum_i \alpha_i = 1, \sum_i \alpha_{ij} = \sum_j \alpha_{ij} = 0 , \sum_i \tau_i = \sum_i \vartheta_{im} = \sum_i \partial_i = 0, \alpha_{ij} = \alpha_{ji}.$$

A convenient feature of the translog specification is that because all variables except time are normalized by their mean values, the first order terms can be interpreted as elasticities at the means of all variables except time. The results derived from estimating the translog cost are used within the decomposition framework that closely resembles the approach proposed by

Gollop and Roberts (1981) for the electric utility industry and Bitzan and Peoples (2014) for the transportation sector. Their approach decomposes productivity changes while holding input prices constant. Hence, their productivity results can be viewed as measures of total factor productivity (TFP).[6] For this study's analysis the influence of input prices on costs are also considered. Including analysis of price effects is critical to airline cost analysis given the potential differences in fuel consumption and use of labor among FSCs and LCCs.

Gollop and Roberts reveal that the decline in average cost over time, when holding prices constant, can be separated into a portion that is attributable to movements along the firm's long-run average cost curve (economies of scale) and a portion that is attributable to shifts in the firm's long-run average cost curve (technical change). That relationship is depicted below by equation (3).

$$\text{Decreasing AC} = -\frac{dlnAC}{dT} = \left(1-\frac{\partial lnC}{\partial lnQ}\right)\frac{\partial lnQ}{\partial T} - \frac{\partial lnC}{\partial T} \qquad (3)$$

where the first component on the right-hand-side of equation (3) denotes decreasing average cost arising from economies of scale and the second component denotes decreasing average cost due to technical change.

While using Gollop and Robert's approach for identifying the components of productivity change is appropriate for many industries, it does not sufficiently identify productivity changes in the airline industry since output can change due to aircrafts carrying more passengers and freight over a given network size or due to airline companies expanding their overall network. Indeed, Keeler (1974) observes that there are two types of potential scale economies in transport industries: (1) returns to density, and (2) returns to firm size. He identifies returns to density as those returns to scale that result from transporting more traffic over a given network size, while he identifies returns to size as returns to scale that results from carrying more traffic as a result of an expanded network. Bitzan and Peoples (2014) show how to adjust the productivity decomposition of Gollop and Roberts to the transportation industries, by separating the effects of density from the effects of firm size. We start by showing the rate of change of total costs (holding input prices constant) as being the sum of the rates of change in total costs resulting from changes in output, network size, firm characteristics, and unexplained technical change:

$$\frac{dlnC}{dT} = \frac{\partial lnC}{\partial lnQ}\frac{\partial lnQ}{\partial T} + \frac{\partial lnC}{\partial lnNS}\frac{\partial lnNS}{\partial T} + \sum_i \frac{\partial lnC}{\partial \ln CHAR_i}\frac{\partial lnCHAR_i}{\partial T} + \frac{\partial lnC}{\partial T}$$

[6] Total Factor Productivity (TFP) is the portion of output growth not explained by increases in the amount of inputs used in production. As such, its level is determined by how efficiently and intensely the inputs are utilized in production (Comin, 2008).

Where the symbol NS denotes network size (number of airports) and the symbol *CHAR* is a vector containing the variables measuring percent of ton-miles that are freight, load factor, and stage length.

The rate of change of average cost is then obtained by subtracting the rate of change in output over time from the rate of change in total costs as depicted by equation (4)

$$\frac{dlnAC}{dT} = \frac{\partial lnC}{\partial lnQ}\frac{\partial lnQ}{\partial T} - \frac{\partial lnQ}{\partial T} + \frac{\partial lnC}{\partial lnNS}\frac{\partial lnNS}{\partial T} + \sum_i \frac{\partial lnC}{\partial \ln CHAR_i}\frac{\partial lnCHAR_i}{\partial T} + \frac{\partial lnC}{\partial T} \quad (4)$$

Bitzan and Peoples (2014) show that the negative of this rate of change in average costs gives the productivity growth equation shown below:

$$-\frac{dlnAC}{dT} = \left(1 - \frac{\partial lnC}{\partial lnQ} - \frac{\partial lnC}{\partial lnNS}\right)\frac{\partial lnNS}{\partial T} + \left(1 - \frac{\partial lnC}{\partial lnQ}\right)\left(\frac{\partial lnQ}{\partial T} - \frac{\partial lnNS}{\partial T}\right) - \sum_i \frac{\partial lnC}{\partial \ln CHAR_i}\frac{\partial lnCHAR_i}{\partial T} - \frac{\partial lnC}{\partial T}$$
(5)

The first component on the right hand side of equation (5) denotes productivity growth resulting from a change in firm size. The second component represents productivity growth resulting from a change in density. The third component denotes productivity growth arising from changes in company characteristics, and the last component denotes productivity growth arising from unexplained technical change. The sum of these components provide total factor productivity, which does not account for cost change attributable to changes in input prices. Following Denny, fuss, Everson and Waverman (1981), we include the product of the input share of total cost and the change in that input's price over time to capture the effect of input prices on cost change. This input price effect is presented as the last component on the equation (6).[7]

$$-\frac{dlnAC}{dT} = \left(1 - \frac{\partial lnC}{\partial lnQ} - \frac{\partial lnC}{\partial lnNS}\right)\frac{\partial lnNS}{\partial T} + \left(1 - \frac{\partial lnC}{\partial lnQ}\right)\left(\frac{\partial lnQ}{\partial T} - \frac{\partial lnNS}{\partial T}\right) - \sum_i \frac{\partial lnC}{\partial \ln CHAR_i}\frac{\partial lnCHAR_i}{\partial T} - \sum_j \frac{P_i X_i}{C} \times \frac{d\,P_i}{dT} - \frac{\partial lnC}{\partial T} \quad (6)$$

For our analysis, cost change resulting from each of these effects is computed using the weighted average of industry characteristics in each year of our data. Specifically, decreases in average cost from the previous year, are separated into the four cost components by using cost function parameter estimates and industry averages of independent variables. Specifically, a two year average of independent variables is used to measure changes due to unexplained technical change, returns to density, returns to firm size, and returns to firm characteristics for any given

[7] The symbol X_i presented in the last component of the right-hand-side of equation (6) denotes factor input *i*.

year.[8] In addition, as depicted in the following equations, the productivity decomposition process uses the mean normalized values of cost determinants since these values are used when estimating the translog cost function.

$$Decreasing\ AC from\ \text{unexplained}\ Tech.Change\ in\ year\ t = -\frac{\partial lnC}{\partial T}\Big|_{YR_t} =$$

$$-\left[\theta + \sum_i \partial_i \left(\frac{\ln\left(\frac{P_i}{\overline{\overline{P_i}}}\right)_t + \ln\left(\frac{P_i}{\overline{\overline{P_i}}}\right)_{t-1}}{2}\right) + \pi\left(\frac{ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_t + ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_{t-1}}{2}\right) + \sum_m \mu_m \left(\frac{ln\left(\frac{a_m}{\overline{\overline{a_m}}}\right)_t + ln\left(\frac{a_m}{\overline{\overline{a_m}}}\right)_{t-1}}{2}\right) + \gamma\left(\frac{T+(T-1)}{2}\right)\right] \quad (7)$$

$$Decreasing\ AC from\ Density\ Economies\ in\ year\ t = \left(1 - \frac{\partial lnC}{\partial lnQ}\Big|_{YR_t}\right)\left(\frac{\partial lnQ}{\partial T}\Big|_{YR_t} - \frac{\partial lnNS}{\partial T}\Big|_{YR_t}\right) =$$

$$\left[1 - \left\{\beta + \sum_i \tau_i \left(\frac{\ln\left(\frac{P_i}{\overline{\overline{P_i}}}\right)_t + \ln\left(\frac{P_i}{\overline{\overline{P_i}}}\right)_{t-1}}{2}\right) + \phi\left(\frac{ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_t + ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_{t-1}}{2}\right) + \sum_m \varphi_m \left(\frac{ln\left(\frac{a_m}{\overline{\overline{a_m}}}\right)_t + ln\left(\frac{a_m}{\overline{\overline{a_m}}}\right)_{t-1}}{2}\right) + \pi\left(\frac{T+(T-1)}{2}\right)\right\}\right]\left[\left(ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_t - ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_{t-1}\right) - (lnNS_t - lnNS_{t-1})\right] \quad (8)$$

$$Decreasing\ \text{AC}\ from\ Size\ Economies\ in\ year\ t = \left(1 - \frac{\partial lnC}{\partial lnQ}\Big|_{YR_t} - \frac{\partial lnC}{\partial lnNS}\Big|_{YR_t}\right)\left(\frac{\partial lnNS}{\partial T}\Big|_{YR_t}\right) =$$

[8] Gollop and Roberts (1981) also used a two year average of independent variables in measuring productivity effects due to scale and technical changes in the U.S. Electric Power Industry.

$$\left[1-\left\{\beta+\sum_i \tau_i\left(\frac{\ln\left(\frac{P_i}{\overline{\overline{P_\iota}}}\right)_t+\ln\left(\frac{P_i}{\overline{\overline{P_\iota}}}\right)_{t-1}}{2}\right)+\phi\left(\frac{ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_t+ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_{t-1}}{2}\right)+\sum_m \varphi_m\left(\frac{ln\left(\frac{a_m}{\overline{\overline{a_m}}}\right)_t+ln\left(\frac{a_m}{\overline{\overline{a_m}}}\right)_{t-1}}{2}\right)+\pi\left(\frac{T+(T-1)}{2}\right)\right\}-\left\{\sigma_{m_{NS}}+\sum_i \vartheta_{im_{NS}}\left(\frac{\ln\left(\frac{P_i}{\overline{\overline{P_\iota}}}\right)_t+\ln\left(\frac{P_i}{\overline{\overline{P_\iota}}}\right)_{t-1}}{2}\right)+\varphi_{m_{NS}}\left(\frac{ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_t+ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_{t-1}}{2}\right)+\sum_n \sigma_{mn_{NS}}\left(\frac{ln\left(\frac{a_m}{\overline{\overline{a_m}}}\right)_t+ln\left(\frac{a_m}{\overline{\overline{a_m}}}\right)_{t-1}}{2}\right)+\mu_{m_{NS}}\left(\frac{T+(T-1)}{2}\right)\right\}\right](lnNS_t-lnNS_{t-1}) \qquad (9)$$

where, NS Є a_m.

$$Decreasing\ AC from\ change\ in\ Char\ m\ in\ year\ t=\left(-\frac{\partial lnC}{\partial lna_m}\bigg|_{YR_t}\right)\left(\frac{\partial lna_m}{\partial T}\bigg|_{YR_t}\right)=$$

$$\left[-\left\{\sigma_m+\sum_i \vartheta_{im}\left(\frac{\ln\left(\frac{P_i}{\overline{\overline{P_\iota}}}\right)_t+\ln\left(\frac{P_i}{\overline{\overline{P_\iota}}}\right)_{t-1}}{2}\right)+\varphi_m\left(\frac{ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_t+ln\left(\frac{Q}{\overline{\overline{Q}}}\right)_{t-1}}{2}\right)+\sum_l \phi_{mn}\left(\frac{ln\left(\frac{a_n}{\overline{\overline{a_n}}}\right)_t+ln\left(\frac{a_n}{\overline{\overline{a_n}}}\right)_{t-1}}{2}\right)+\mu_m\left(\frac{T+(T-1)}{2}\right)\right\}\right]\left[\left(ln\left(\frac{a_m}{\overline{\overline{a_m}}}\right)_t-ln\left(\frac{a_m}{\overline{\overline{a_m}}}\right)_{t-1}\right)\right]$$

Decreasing AC from changes in factor input prices in year t=

$$-\sum_i \frac{P_iX_i}{C}\times\frac{\partial lnP_i}{\partial t}=\left\{\left(\frac{\left(\frac{P_1X_1}{C}\right)_t+\left(\frac{P_1X_1}{C}\right)_{t-1}}{2}\right)\left(ln\left(\frac{P_1}{\overline{\overline{P_1}}}\right)_t-ln\left(\frac{P_1}{\overline{\overline{P_1}}}\right)_{t-1}\right)+\left(\frac{\left(\frac{P_2X_2}{C}\right)_t+\left(\frac{P_2X_2}{C}\right)_{t-1}}{2}\right)\left(ln\left(\frac{P_2}{\overline{\overline{P_2}}}\right)_t-ln\left(\frac{P_2}{\overline{\overline{P_2}}}\right)_{t-1}\right)+\left(\frac{\left(\frac{P_3X_3}{C}\right)_t+\left(\frac{P_3X_3}{C}\right)_{t-1}}{2}\right)\left(ln\left(\frac{P_3}{\overline{\overline{P_3}}}\right)_t-ln\left(\frac{P_3}{\overline{\overline{P_3}}}\right)_{t-1}\right)+\left(\frac{\left(\frac{P_4X_4}{C}\right)_t+\left(\frac{P_4X_4}{C}\right)_{t-1}}{2}\right)\left(ln\left(\frac{P_4}{\overline{\overline{P_4}}}\right)_t-ln\left(\frac{P_4}{\overline{\overline{P_4}}}\right)_{t-1}\right)\right\} \qquad (10)$$

In equation (10) the variables P_1, P_2, P_3 and P_4 represent input prices for labor, fuel, capital and other inputs. The specification of this equation indicates that the direction of the price effect on cost is due exclusively to the direction of the change in input prices, while the size of input cost shares exclusively influence the magnitude of this change. The opportunity for further analysis of input price effects on airline operations is obtained from examining the translog parameter estimates of the input price-time interactions and input price-output interactions. These parameter estimates provide useful information identifying whether technology is factor using or factor saving for the different factors of production. For instance, a positive time-factor price interaction suggests that technology is factor using for that factor and that an increase in the factor price hinders technical change – if opportunities for technical change are associated with that factor of production, adopting those technologies are now more expensive. In contrast, a negative time-factor price interaction suggests that technology is factor saving for that technology and that an increase in the factor price accelerates technical change – if opportunities for technical change are associated with other factors of production, the price increase encourages a switch to those technologies. A positive output-factor price interaction suggest the scale of an airline's operation increases the factor share of the input. Hence, compared to small carriers large carriers are susceptible to more expensive operations from a factor price increase if size is associated with higher input share.

IV. Empirical Results

A. *Cost Findings*

Estimation results for the three carrier types are presented in Table 8.[9] As the table shows, while all three cost function estimations show a good overall fit, there are important differences among the cost functions for each type of carrier.

As mentioned previously, because all variables except time are normalized by their mean values, first-order terms can be interpreted as elasticities when all variables except time are at their mean levels.[10] In examining factor shares at the mean values of all variables, some obvious differences are apparent among the various carrier types. Labor accounts for about 29 percent of the average FSC carriers' costs, while it only accounts for 23.8 percent and 24.1 percent of the average LCC and 'other carriers'' costs, respectively. This likely reflects higher wages and less flexibility embedded in FSC labor contracts, in comparison to labor contracts for the other two carrier types. Furthermore, important differences are also apparent in fuel and other factors of production shares. Fuel accounts for 24.5 percent of the average LCC carrier's costs, while it only accounts for 19 percent and 20 percent of the average FSC and 'other carriers'' costs,

[9] Regional carriers and charter carriers are combined into one "other" category for analysis.

[10] Elasticities when all variables are placed at their mean levels can be obtained by multiplying the interaction term between time and the variable of interest by the mean value of time and adding it to the first order term. For example the elasticity of cost with respect to labor price at the mean of all variables for the FSC sample is .2910 + .0002 x 9.67 = .293, where 9.67 is the mean of time in the FSC sample. Means of time are 9.67, 10.78, and 10.33 in the FSC, LCC, and other samples, respectively.

respectively.[11] Other factors of production account for about 38 percent of "other" carrier costs, while they only account for 35 percent and 33 percent of FSC and LCC costs, respectively.

The parameter estimates on revenue-ton miles also show important differences in returns to density for the different types of carriers. As Table 8 shows, the elasticity of costs with respect to ton-miles is .89 for LCCs, .85 for FSCs, and .77 for 'other carriers', at the point of means for all variables except time. This suggests that the average carrier of each type is operating at increasing returns to density. However, when examining the elasticity of costs with respect to output at the means of all variables (including time), it is apparent that FSCs are characterized by constant returns to density, while LCCs and 'other carriers' are characterized by increasing returns to density.

The low cost elasticity at the point of means for 'other carriers' (0.82) and LCCs (0.83) in comparison to FSCs (1.02) likely reflects the very low traffic densities of LCCs and 'other carriers', and the resulting opportunities for cost savings with more traffic.

The parameter estimate for the number of airports has an unexpected negative sign for both FSCs and LCCs, although it is not statistically significant for FSCs. When taking into account the interaction with time, the elasticity of costs with respect to the number of airports at the point of means of all variables (including time) is roughly zero for FSCs (-.016) and is -.108 for LCCs. While it is difficult to explain this counterintuitive sign and statistically significant sign for LCCs, a focus on secondary airports (as encompassed in the LCC business model) does suggest a smaller positive impact from serving more airports (i.e. smaller charges per airport). The negative sign on the number of airports for LCCs and the lack of a significant positive sign for FSCs may reflect some other unmeasured characteristic of the business models of LCCs and FSCs that serve a large number of airports.[12] In contrast, the elasticity of costs with respect to the number of airports at the point of means is .254 for other carriers, suggesting that a given amount of traffic is more expensive to carry over more airports. Combined with the elasticity of costs with respect to output, these suggest roughly constant to slightly decreasing returns to size for FSCs and 'other' carriers – i.e. a one percent increase in output as a result of a one percent increase in network size leads to a 1.00 percent increase in costs for FSCs and a 1.08 percent increase in costs for 'other carriers', at the means of all variables (including time). For LCCs, increasing returns to size are shown, with a one percent increase in output from a one percent increase in network size leading to a .72 percent increase in costs.[13]

As expected, the elasticity of costs with respect to average stage length and load factor are negative for all carrier types at the means of all variables. The negative sign on the parameter estimate for stage length reflects economies of flight distance, as many airline costs vary less

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[11] For LCCs at the average of all variables, Fuel Share = .2525 - .0007 x 10.78.

[12] Recall that business models used by LCCs and FSCs vary. The LCC and FSC business model descriptions are only meant to describe the strategies that are common to many LCCs and FSCs. Different LCCs and FSCs employ these strategies to varying degrees. Moreover, the strategies described are not comprehensive of the strategies employed by all LCCs and FSCs.

[13] Returns to size are assessed by adding the elasticity of costs with respect to output to the elasticity of costs with respect to network size.

than proportionally with distance – e.g. fueling, boarding, luggage loading, security fees, and maintenance costs. The negative sign on the parameter estimate for load factor reflects the fact that many costs vary less than proportionally with the number of passengers – e.g. maintenance costs, fuel costs, flight crew, etc.

The percent of ton-miles attributable to freight has a negative sign for FSCs and 'other' carriers, and a positive sign for LCCS, although it is not statistically significant for 'other' carriers. The negative sign for FSCs likely reflects the fact that passenger operations are the primary cost driver in airline operations, with all FSCs routinely handling freight in the belly of the aircraft. On the other hand, since many LCCs don't handle freight at all, the positive sign for LCCs likely reflects a difference in the business model used by LCCs that handle freight versus those that don't.

Interestingly, the first order term on the time trend shows that unexplained technical change is positive for FSC and 'other carriers' at the point of means, while it is negative for LCCs at the point of means. However, the time trend is only significant in the LCC equation.

As highlighted in the methodology section, important insights into technical change can be obtained by examining time-input price interactions. As Table 8 shows, technology is labor saving, while it is capital using for LCCs. This suggests that increases in labor prices have accelerated technical change for LCCs, encouraging them to use labor-saving technologies. For FSCs, technology is fuel saving, and capital using. This is supported by the fact that fuel price increases have led to investments in more fuel efficient aircraft. For 'other carriers', the time-input price interactions suggest that technology is labor and fuel using, and other materials saving. This may suggest that regional carriers have had more difficulty employing technologies that substitute for fuel and labor.

The methodology section also reveals the important insights obtained by examining the output (RTM)- input price interactions. The parameter estimates on these interaction terms presented in Table-8 indicate that scale is associated with increasing labor cost share for FSCs and LCCs. This suggests increasing output is associated with more labor intensive operations. Such findings provide further rationale for negotiating for greater labor flexibility. The parameter estimate on the fuel price-output interaction term is only statistically significant for FSCs and is positive, which also supports FSCs emphasis on investing in fuel efficient aircrafts as they grow their operations.

The next section of this study breaks down the sources of cost savings over time for the three types of carriers. In addition to examining productivity effects, we also examine the impacts of factor price changes on costs.

B. *Productivity Findings*

Tables 9, 10, and 11 show the estimated yearly changes in average costs resulting from productivity gains and from changes in input prices for the three types of carriers. Our measure of productivity change accounts for cost savings from changing the scale of operations, and from shifts in the average cost function over time (technical change). Moreover, in evaluating technical change, we account for technical change that is embedded in changes in movement characteristics (e.g. changes in freight percentage, average stage length, and load factor). We also distinguish between two types of scale economies encountered in the transportation industries – economies of density and economies of size.

For each type of carrier, the tables show the annual changes in firm density, size, and movement characteristics, as well as the productivity gains resulting from such changes. Specifically, each table shows: (1) annual productivity gains resulting from changes in firm output, leaving network size constant (gains from changes in traffic density), (2) annual productivity gains resulting from changes in output that are a result of a change in the number of airports served (gains from changes in firm size), (3) annual productivity gains resulting from changes in movement characteristics (freight percentage, load factor, and stage length), (4) annual productivity gains resulting from unexplained technical change (time trend), and (5) annual changes in costs resulting from changes in input prices. We compute average cost savings using annual weighted averages of industry characteristics, using the methodology highlighted in Section III.[14]

Table 9 shows the annual cost savings realized by full service carriers between 1993 and 2014. As the table shows, FSCs experienced a large increase in traffic density (71 percent increase) and a decrease in firm size (3 percent decrease) over this time period. However, because FSCs realize roughly constant returns to density and to firm size, these changes in density and firm size had negligible impacts on average costs.

The table also shows large increases in average load factor and average stage length, and a large decrease in freight percentage for the FSCs. Average load factor increased by 28 percent over this period, average stage length increased by more than 45 percent, and average freight percentage decreased by 40 percent. These changes led to large cost savings of more than 49 percent. While these types of cost savings are often not counted as part of technical change, we argue (as in Bitzan and Peoples, 2014) that much of these cost savings are embedded in technical change. Large portions of the increases in load factors and stage lengths are due to innovations in business models aimed at enhancing efficiency.

Unexplained technical change captured by the time trend shows decrease in average costs of about 2 percent over this time period. When combining the effects on average cost from changes in density, firm size, movement characteristics, and unexplained technical change, the total factor productivity gains are in excess of 49 percent for the FSCs over this time period.

Finally, increased input prices resulted in average costs increasing more than 39 percent over this period for the FSCs. Between 1993 and 2014, FSCs experienced a 23 percent increase in the price of labor, a 124 percent increase in the price of fuel, a 31 percent increase in the price of other materials, and a 16 percent decrease in the price of capital (changes in input prices not

[14] Averages for all variables except ton-miles are weighted by ton-miles. Ton-mile averages are simple averages. Because we are using industry weighted averages, our measured productivity gains capture changes in the composition of firms in the industry as well as productivity changes.

shown). These increased input prices offset the productivity gains somewhat, resulting in an overall estimated 10 percent reduction in average costs over the period.

Table 10 shows the annual cost savings realized by low-cost carriers between 1993 and 2014. As the table shows, like FSCs, the LCCs had a large increase in traffic density and a small decrease in firm size over this time period. But, unlike the FSCs, because of the increasing returns to density and firm size, these changes had important impacts on average costs. Cost savings from increased density amounted to nearly 38 percent over this period, while cost increases from decreasing firm size led to a 2 percent increase in costs.

Table 10 also shows about a 18 percent increase in the average load factor, a 12 percent decrease in average stage length, and a large reduction in freight percentage (difference in logs of -1.66) for the LCCs over this period. Despite the cost saving impact of an increase in load factor and a decrease in freight percentage, the overall effect of these changes on LCC average costs is small due to the cost hindering impact of shorter stage lengths. In total, changes in movement characteristics resulted in about a .2 percent decrease in average costs.

The impact of unexplained technical change was large for LCCs over this period, at nearly a 68 percent increase in costs. In total, changes in density, firm size, movement characteristics, and unexplained technical change resulted in total factor productivity losses of nearly 32 percent for the LCCs over this period.

Table 10 shows that the cost saving impact of input price changes were not large enough to offset the decline in productivity for the LCCs, resulting in an overall cost increase of more than 8 percent over this period. Despite a 115 percent increase in the price of fuel and a 36 percent increase in the price of labor, the LCCs realized huge decreases in the price of capital (81 percent) and in the price of other materials (difference in logs of -1.26), resulting in an overall decrease in average costs from the changes in input prices of 23 percent.

Annual changes in average costs for ‘other carriers’ are shown in Table 11. As the table shows, ‘other carriers’ had a 41 percent increase in density and a 49 percent increase in size over the 1993-2014 period. Although ‘other carriers’ show increasing returns to density at the point of means and slightly decreasing returns to firm size at the point of means, these changes had a small impact on average costs (about 4 percent cost savings).

‘Other carriers’ also had increases in average load factor and average stage length of 21 percent and 42 percent, respectively over the period. They experienced a 21 percent reduction in freight percentage. These changes resulted in cost savings of about 17 percent since 1993.

Unlike the LCCs, unexplained technical change was positive for the ‘other carriers’. This change resulted in a 31 percent cost saving over this time period. This may be due to the recent innovations that have occurred in regional aircraft. Leick and Wensveen (2014) note that Embraer and Bombardier have introduced newer more efficient narrow-body aircraft that have allowed regional carriers to bypass congested hub airports. In total, after accounting for cost increases resulting from increases in labor price, fuel price, capital price, and other materials price, we estimate about a 20 percent decrease in “other” carrier costs over this period.

One thing that is particularly interesting about 'other carriers' is that much of the cost savings that occurred over the 1993-2014 time period have occurred since 2010. For example, density has increased by about 45 percent and size has decreased by about 13 percent since 2010. These have led to cost savings of more than 10 percent since 2010. Similarly, technical change has resulted in savings in excess of 9 percent since 2010. Moreover, recent input price decreases have resulted in cost savings of nearly 14 percent since 2010.

V. Concluding Remarks

Increasing competitiveness following regulatory reform in the airline industry places a premium on carriers' abilities to save costs. Indeed, the post reform era in the US airline industry has been heavily influenced by the performance of low cost carriers. Their prominence in the industry creates a challenge to full service (legacy) carriers who have been forced to take steps to become more cost competitive. At issue is whether the US airline industry has experienced cost convergence among LCCs and full service carriers. This study addresses this question by exploring the sources of productivity gains for LCCs, full service carriers, and other carriers such as regional and charter carriers. Identifying the source of productivity gains contributes to our understanding business models that are more appropriate for facilitating cost savings across carrier groups.

Findings for weighted average cost reveals cost declines for FSCs and 'other' carriers, and cost increases for LCCs. We estimate average cost declines of 10 percent for FSCs and 20 percent for 'other' carriers, and cost increases of 8.5 percent for LCCs for the 1993-2014 sample. Such findings suggest cost convergence between LCCs and FSCs in this industry. LCCs, though retain their cost advantage throughout the sample observation even though the advantage has eroded.

Findings on productivity decomposition reveal sources contributing to cost savings differ for FSC, LCC, and 'other' carriers. FSCs have benefitted from nontrivial productivity gains due to changes in load factor and stage length. Unexplained technical change accounts for the cost increases for LCCs; and productivity gains due to changes in load factor, stage length and unexplained technical change contribute to cost declines for 'other' carriers.

For FSCs, these findings are interpreted as suggesting that any efficiency improvements that occurred from mergers and acquisitions were likely from increases in load factors and stage lengths, rather than from increases in system density or firm size. Moreover, cost findings for FSCs provide evidence revealing the importance of the hub and spoke network system due to its ability to promote high load factors. In addition, FSC cost findings indicate the benefits of relying on feeder carriers for short hauls and focusing on long haul routes to take advantage of cost savings associated with longer stage lengths. Findings on input price effects for LCCs (from reductions in capital and other materials prices) are consistent with this carrier group's history of negotiating low prices from suppliers. Moreover, the negative technical change estimated for LCCs is consistent with the idea that they are starting to use some FSC strategies, potentially eroding some of their cost advantages. For example, previous research suggests

LCCs are starting to use some hubs, adding more frills, offering premium class service, using multiple aircraft types, and serving larger airports. This may mean less opportunities for savings in: (1) ground crews, maintenance, etc. from serving a point to point network, (2) parts and training from using a uniform fleet, (3) congestion, delay, and airport charges from serving secondary airports, (4) analytics from simplified yield management, and (5) ancillary costs from no-frills service. Findings on unexplained technical change for 'other' carriers suggest gains from increasing specialization, as these findings comport well with the notion that investments in increasingly specialized equipment by efficient regional carriers have allowed this group of carriers to achieve cost savings that are unique.

In sum, during the recent period of stepped-up competition in the US airline industry carriers in the FSC and 'other' category have experienced cost savings, while there has been a slight increase in costs for LCCs. The sources of cost changes are tied to the unique characteristics of each classification group. The widespread cost savings associated with these productivity gains suggest air transport passengers and freight shippers are the primary beneficiaries of such competition.

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Table 1: Descriptive Statistics (all prices are in 2009 $)		
Variable	**Mean**	**Standard Deviation**
Cost per Available Seat-Mile ($)	0.1502	0.0617
Cost per Ton-Mile ($)	2.1567	1.2727
Load Factor	0.7057	0.1016
Stage Length	834.59	546.63
Ton-Miles	2,697,779,361	4,461,864,279
Airports	134.44	92.73
Labor Price ($)	69,698	20,777
Fuel Price ($)	1.5728	0.8619
Capital Price ($)	1,799	2,525
Other Price ($)	3,118	4,933
Labor Share	0.2618	0.0685
Capital Share	0.1992	0.0633
Fuel Share	0.1952	0.0923
Other Share	0.3439	0.0891
*638 Observations		

Table 2: 1993 Air Carrier Characteristics (costs in 2009 $)									
Full Service Carriers									
Carrier	**Cost per Available Seat-Mile**	**Cost per Ton-Mile**	**Avg. Load Factor (%)**	**Avg. Stage Length**	**Density (ton-miles per airport) (millions)**	**Airports**	**Available Seat Miles per Employee (millions)**	**Labor Share**	**Fuel Share**
Alaska Airlines	$0.149	$2.23	58.5	651.8	5.6	113	1.6	.31	.11
American Airlines	$0.132	$1.84	60.4	975.4	49.5	234	1.8	.34	.11
Continental Airlines	$0.115	$1.57	63.4	845.2	20.1	231	1.7	.27	.14
Delta Airlines	$0.138	$1.92	62.3	750.2	41.4	232	1.9	.37	.11
Northwest Airlines	$0.132	$1.44	66.7	842.7	41.1	196	2.1	.32	.13
Trans World Airways	$0.132	$1.75	63.5	808.1	15.7	172	1.4	.35	.14
United Airlines	$0.135	$1.67	67.2	1012.3	57.8	210	1.9	.33	.11
US Airways	$0.165	$2.58	59.4	536.0	26.3	146	1.3	.40	.10
Weighted Average[15]	**$0.135**	**$1.78**	**63.6**	**867.6**	**34.7**	**211.2**	**1.8**	**.34**	**.12**

Table 3: 1993 Air Carrier Characteristics (costs in 2009 $)									
Low Cost Carriers									
Carrier	**Cost per Available Seat-Mile**	**Cost per Ton-Mile**	**Avg. Load Factor (%)**	**Avg. Stage Length**	**Density (ton-miles per airport) (millions)**	**Airports**	**Available Seat Miles per Employee (millions)**	**Labor Share**	**Fuel Share**
ATA Airlines	$0.075	$1.12	67.0	1354.7	1.6	363	3.4	.24	.18
Midwest Airline	$0.159	$2.34	59.9	681.2	1.1	87	1.3	.28	.15
Southwest Airlines	$0.108	$1.56	67.7	376.5	14.3	121	2.0	.33	.14
Sun Country Airlines	$0.070	$0.86	81.9	1288.6	1.2	180	5.2	.19	.21
Tower Air	$0.111	$1.12	78.9	3035.9	3.3	123	4.5	.19	.19
Weighted Average	**$0.101**	**$1.39**	**69.9**	**997.3**	**3.5**	**171.6**	**2.4**	**.28**	**.16**

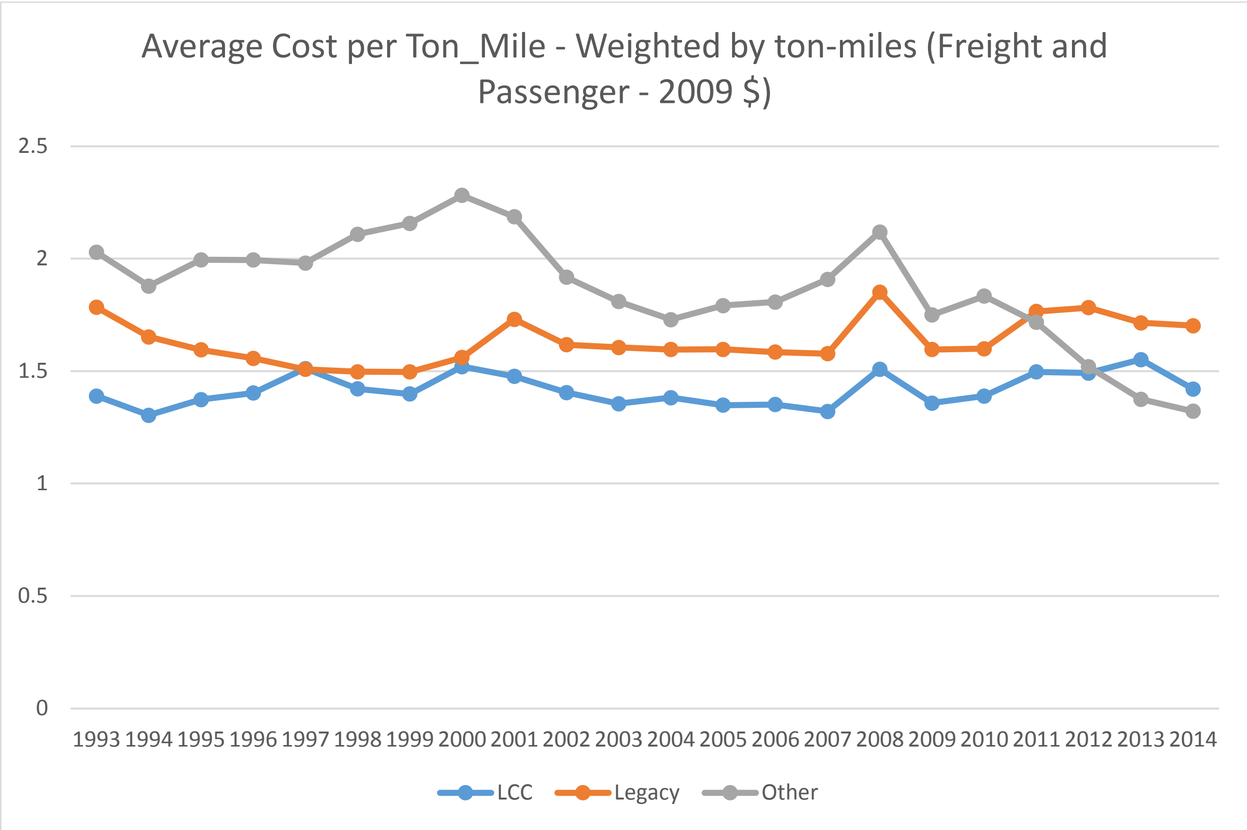
[15] Weights used in Tables 2-7 are as follows: cost per available seat-mile is weighted by available seat miles; cost per ton-mile, average load factor, average stage length, airports, labor share, and fuel share are weighted by ton-miles; density is weighted by number of airports; available seat miles per employee are weighted by number of employees.

Table 4: 1993 Air Carrier Characteristics (costs in 2009 $)									
Other Carriers									
Carrier	**Cost per Available Seat-Mile**	**Cost per Ton-Mile**	**Avg. Load Factor (%)**	**Avg. Stage Length**	**Density (ton-miles per airport) (millions)**	**Airports**	**Available Seat Miles per Employee (millions)**	**Labor Share**	**Fuel Share**
Air Wisconsin Airlines	$0.431	$8.43	50.6	157.2	38.1	1	0.7	0.24	0.06
Aloha Airlines	$0.300	$4.18	61.1	130.4	10.5	7	0.6	0.38	0.11
America West Airlines	$0.103	$1.47	65.3	644.2	13.1	92	1.8	0.25	0.13
ExpressJet Airlines	$0.254	$5.40	46.8	235.5	0.6	64	0.4	0.24	0.08
Hawaiian Airlines	$0.114	$1.39	74.3	278.8	12.2	26	1.7	0.33	0.15
Horizon Air	$0.307	$5.19	56.8	163.8	1.6	37	0.5	0.35	0.08
Markair	$0.129	$1.78	61.4	610.7	2.8	47	1.7	0.23	0.15
US Air Shuttle	$0.306	$6.59	46.3	198.8	0.9	35	0.9	0.32	0.10
Westair Airlines	$0.258	$4.67	55.2	175.7	0.5	41	0.4	0.25	0.12
Weighted Average	**$0.141**	**$2.03**	**65.0**	**517.1**	**5.5**	**69.2**	**1.3**	**0.27**	**0.13**

Table 5: 2014 Air Carrier Characteristics (costs in 2009 $)									
Full Service Carriers									
Carrier	**Cost per Available Seat-Mile**	**Cost per Ton-Mile**	**Avg. Load Factor (%)**	**Avg. Stage Length**	**Density (ton-miles per airport) (millions)**	**Airports**	**Available Seat Miles per Employee (millions)**	**Labor Share**	**Fuel Share**
Alaska Airlines	$0.131	$1.50	85.7	1182.5	36.0	79	3.3	.24	.25
American Airlines	$0.151	$1.59	82.1	1326.0	102.0	146	2.6	.23	.27
Delta Airlines	$0.169	$1.75	85.4	1176.5	77.0	266	2.8	.24	.30
United Airlines	$0.162	$1.71	83.6	1727.1	90.6	225	2.7	.24	.25
US Airways	$0.164	$1.87	83.0	1025.1	50.8	138	2.5	.21	.23
Weighted Average	**$0.160**	**$1.70**	**83.8**	**1365.6**	**76.8**	**204.2**	**2.7**	**.24**	**.27**

Table 6: 2014 Air Carrier Characteristics (costs in 2009 $)									
Low Cost Carriers									
Carrier	**Cost per Available Seat-Mile**	**Cost per Ton-Mile**	**Avg. Load Factor (%)**	**Avg. Stage Length**	**Density (ton-miles per airport) (millions)**	**Airports**	**Available Seat Miles per Employee (millions)**	**Labor Share**	**Fuel Share**
Allegiant Air	$0.105	$1.18	89.2	946.1	3.9	204	4.0	.21	.39
Frontier Airlines	$0.101	$1.14	89.0	903.7	10.1	110	3.4	.20	.37
JetBlue Airways	$0.116	$1.38	84.0	1085.5	30.5	125	3.3	.24	.33
Southwest Airlines	$0.130	$1.55	82.5	718.3	48.2	213	2.7	.33	.29
Spirit Airlines	$0.089	$1.03	86.3	982.0	30.8	46	4.4	.20	.36
Sun Country Airlines	$0.108	$1.48	72.1	1144.0	1.1	269	3.2	.18	.32
Virgin America	$0.105	$1.28	82.4	1466.1	42.1	24	4.9	.21	.33
Weighted Average	**$0.120**	**$1.42**	**83.6**	**880.7**	**18.9**	**166.5**	**3.1**	**.28**	**.32**

Table 7: 2014 Air Carrier Characteristics (costs in 2009 $)									
Other Carriers									
Carrier	**Cost per Available Seat-Mile**	**Cost per Ton-Mile**	**Avg. Load Factor (%)**	**Avg. Stage Length**	**Density (ton-miles per airport) (millions)**	**Airports**	**Available Seat Miles per Employee (millions)**	**Labor Share**	**Fuel Share**
Air Wisconsin Airlines	$0.216	$2.76	78.2	361.0	2.4	94	1.2	.24	.34
Hawaiian Airlines	$0.116	$1.23	81.3	819.0	89.6	18	3.6	.22	.30
Miami Air Internatio nal	$0.163	$3.28	49.8	804.3	0.1	259	1.9	.25	.21
North American Airlines	$0.197	$4.10	48.1	3504.5	0.2	36	0.7	.26	.28
Omni Air Express	$0.094	$1.47	63.5	2974.9	2.2	100	4.2	.26	.30
SkyWest Airlines	$0.094	$1.13	83.4	497.2	7.2	214	1.9	.36	.09
Vision Airlines	$0.099	$1.54	64.0	331.6	0.2	98	1.3	.28	.15
Weighted Average	**$0.113**	**$1.32**	**80.5**	**786.5**	**4.5**	**113.1**	**2.3**	**0.28**	**0.22**



Average Cost per Ton_Mile - Weighted by ton-miles (Freight and Passenger - 2009 $)
2.5
2
1.5
1
0.5
0
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
LCC
Legacy
Other

Table 8: Seemingly Unrelated Estimation of Airline Costs, 1993-2010

Variables	**Full Service (FSC)**	**Low Cost (LCC)**	**Other**
Dependent			
Log of total cost			
Explanatory (logs)			
Intercept	23.5231	20.6137	21.2407
	(448.69)	(137.59)	(192.59)
Labor Price	0.2910	0.2690	0.2052
	(39.58)	(27.33)	(23.45)
Capital Price	0.1576	0.1470	0.2064
	(55.82)	(20.08)	(50.30)
Other Price	0.3487	0.3315	0.4175
	(60.04)	(34.25)	(65.17)
Fuel Price	0.2027	0.2525	0.1709
	(41.32)	(22.77)	(23.30)
Revenue Ton-Miles	0.8528	0.8934	0.7736
	(15.65)	(15.84)	(12.30)
Average Stage Length	-0.2608	-0.4730	-0.3950
	(-1.63)	(-4.77)	(-4.29)
Load Factor	-0.2478	-2.9629	-0.0926
	(-0.40)	(-7.79)	(-0.29)
Time	-0.0026	0.0773	-0.0100
	(-0.24)	(7.49)	(-1.20)
Airports	-0.0407	-0.3081	0.4001
	(-0.40)	(-6.74)	(7.40)
FreightPct	-0.1750	0.0379	-0.0040
	(-2.48)	(5.38)	(-0.65)
½ Labor Price^2	0.2014	0.0975	0.0543
	(25.55)	(12.21)	(7.56)
½ Capital Price^2	0.1445	0.1193	0.1064
	(52.53)	(23.61)	(46.22)
½ Other Price^2	0.2157	0.1290	0.1186
	(41.67)	(22.56)	(36.65)
½ Fuel Price^2	0.1463	0.0925	0.0688
	(40.97)	(12.84)	(13.35)
½ Ton-Miles^2	0.0935	-0.0002	0.1357
	(1.94)	(-0.01)	(4.44)
½ Stage^2	1.2873	0.5340	0.4531
	(2.56)	(2.37)	(7.02)
½ LOAD^2	7.8698	-5.4765	3.4291
	(2.08)	(-2.18)	(3.35)

½ $Time^2$	0.0004	-0.0051	-0.0003
	(0.36)	(-6.83)	(-0.48)
½ $Airports^2$	0.0492	-0.1376	0.1401
	(0.51)	(-4.84)	(6.34)
½ $FreightPct^2$	-0.0812	0.0000	0.0000
	(-1.08)	(5.38)	(-0.64)
Labor Price x Cap Price	-0.0506	-0.0164	0.0082
	(-14.15)	(-3.60)	(2.95)
Labor Price x Other Price	-0.0879	-0.0390	0.0009
	(-15.84)	(-7.35)	(0.23)
Labor Price x Fuel Price	-0.0628	-0.0421	-0.0634
	(-16.99)	(-6.95)	(-12.94)
Labor Price x Ton-Miles	0.0186	0.0139	-0.0152
	(5.32)	(4.51)	(-3.46)
Labor Price x FreightPct	0.0049	0.0000	0.0000
	(1.02)	(1.90)	(2.22)
Labor Price x Stage	0.0045	0.0027	-0.0345
	(0.53)	(0.31)	(-4.99)
Labor Price x LOAD	-0.2253	-0.0883	0.0732
	(-5.64)	(-2.35)	(2.66)
Labor Price x Time	0.0002	-0.0029	0.0035
	(0.25)	(-3.44)	(5.08)
Labor Price x Airports	-0.0012	0.0158	-0.0027
	(-0.17)	(4.66)	(-0.66)
Fuel Price x Other Price	-0.0587	-0.0187	-0.0051
	(-16.81)	(-3.85)	(-1.74)
Fuel Price x Capital Price	-0.0248	-0.0317	-0.0003
	(-14.00)	(-7.25)	(-0.12)
Fuel Price x Ton-Miles	0.0105	-0.0024	0.0054
	(4.78)	(-0.81)	(1.47)
Fuel Price x FreightPct	0.0326	0.0000	0.0000
	(11.05)	(-2.53)	(-0.79)
Fuel Price x Stage	-0.0095	0.0523	0.0535
	(-1.82)	(6.19)	(9.48)
Fuel Price x LOAD	0.0965	0.2427	0.0786
	(3.97)	(6.56)	(3.31)
Fuel Price x Time	-0.0010	-0.0007	0.0032
	(-2.14)	(-0.70)	(5.24)
Fuel Price x Airports	-0.0194	0.0160	-0.0071
	(-4.72)	(4.82)	(-2.02)
Other Price x Capital Price	-0.0690	-0.0713	-0.1144
	(-28.50)	(-18.33)	(-56.68)
Other Price x Ton-Miles	-0.0196	-0.0096	0.0063
	(-7.23)	(-3.10)	(1.96)
Other Price x FreightPct	-0.0292	0.0000	0.0000

	(-7.86)	(1.53)	(0.49)
Other Price x Stage	-0.0073	-0.0305	-0.0231
	(-1.11)	(-3.48)	(-4.25)
Other Price x LOAD	0.1166	-0.0668	-0.1034
	(3.80)	(-1.72)	(-4.92)
Other Price x Time	0.0002	0.0003	-0.0039
	(0.28)	(0.37)	(-7.39)
Other Price x Airports	0.0207	-0.0213	0.0071
	(3.98)	(-6.10)	(2.25)
Capital Price x Ton-Miles	-0.0095	-0.0019	0.0035
	(-7.29)	(-0.92)	(1.69)
Capital Price x FreightPct	-0.0083	0.0000	0.0000
	(-4.66)	(-1.43)	(-3.93)
Capital Price x Stage	0.0122	-0.0245	0.0041
	(3.74)	(-4.05)	(1.21)
Capital Price x LOAD	0.0122	-0.0875	-0.0484
	(0.81)	(-3.38)	(-3.60)
Capital Price x Time	0.0007	0.0032	-0.0028
	(2.43)	(5.19)	(-8.18)
Capital Price x Airports	-0.0002	-0.0105	0.0027
	(-0.08)	(-4.55)	(1.37)
Ton-Miles x Stage	-0.1890	0.3380	-0.1368
	(-1.88)	(5.64)	(-4.06)
Ton-Miles x LOAD	-0.6807	-0.1445	-0.4403
	(-2.81)	(-0.95)	(-3.32)
Ton-Miles x Time	0.0177	-0.0057	0.0048
	(3.90)	(-2.39)	(1.26)
Ton-Miles x Airports	-0.0370	-0.0344	-0.0382
	(-0.51)	(-2.08)	(-1.74)
Ton-Miles x FreightPct	-0.0965	0.0000	0.0000
	(-2.18)	(-4.92)	(-0.07)
FreightPct x Stage	0.1309	0.0000	0.0000
	(1.08)	(-1.04)	(2.47)
FreightPct x LOAD	-0.0663	0.0001	0.0000
	(-0.20)	(3.43)	(-1.71)
FreightPct x Time	-0.0042	0.0000	0.0000
	(-0.62)	(1.94)	(1.50)
FreightPct x Airports	0.1784	0.0000	0.0000
	(2.22)	(-2.31)	(0.18)
Stage x Time	-0.0113	-0.0340	-0.0007
	(-0.76)	(-4.73)	(-0.15)
Stage x LOAD	-0.4246	0.3714	0.8734
	(-0.82)	(0.90)	(4.14)
Stage x Airports	-0.4105	-0.3844	-0.0873
	(-2.95)	(-6.81)	(-2.19)

LOAD x Time	-0.1440	0.2061	-0.0333
	(-2.27)	(6.51)	(-1.37)
LOAD x Airports	0.7322	0.0324	0.2561
	(1.65)	(0.20)	(2.34)
Airports x Time	0.0025	0.0186	-0.0141
	(0.30)	(5.76)	(-4.44)

t-ratios in parentheses

Table-9

Annual Full Service Carrier Cost Savings Due to Productivity Growth from Changes in Density, Firm Size, Movement Characteristics, and Technical Change, and from Changes in Input Prices

		Annual Changes in Firm Density, Size, and Movement Chars.				Annual Cost Savings (positive indicates savings)						
Year	Density Change	Size Change	Load Factor Change	Stage Length Change	Freight Share Change	Density	Firm Size	Movement Chars.	Unexplained Technical Change	Total Factor Productivity	Input Prices	Total
1994	0.04849	-0.00813	0.046783	0.01510	0.015768	0.002203	-.000444020	0.075651	-0.019912	0.057499	0.02284	0.08034
1995	0.01542	-0.00027	0.015831	0.03222	-0.022342	0.000808	-.000012639	0.028688	-0.015490	0.013993	0.00863	0.02263
1996	0.02908	0.02183	0.035430	0.02633	-0.035782	0.001577	0.000985380	0.047320	-0.011813	0.038070	-0.00923	0.02884
1997	0.08583	-0.03172	0.018596	0.01658	0.036930	0.005046	-.001167853	0.037196	-0.007832	0.033242	0.00708	0.04032
1998	0.01187	-0.00124	0.001776	0.03045	-0.030398	0.000640	-.000035908	0.005948	-0.006523	0.000029	0.01986	0.01988
1999	0.01523	0.02980	0.001757	0.01388	0.026352	0.000665	0.000642462	0.013592	-0.006562	0.008337	0.00167	0.01000
2000	0.06463	-0.01419	0.020466	0.01402	0.013856	0.002374	-.000139212	0.038517	-0.004969	0.035783	-0.05857	-0.02279
2001	-0.13872	0.03867	-0.036742	0.01640	-0.075776	-0.001691	0.000135457	-0.073412	-0.006442	-0.081409	-0.04092	-0.12233
2002	0.03484	0.05630	0.034161	0.01465	0.003428	-0.000194	-.000344258	0.068239	-0.007247	0.060455	0.00324	0.06369
2003	-0.12695	0.08971	0.024638	0.03974	-0.025995	-0.000339	-.001081223	0.051286	-0.003313	0.046553	-0.05034	-0.00379
2004	0.15736	-0.07381	0.029515	0.04109	-0.014579	0.001439	0.000463670	0.058857	0.000792	0.061551	-0.06727	-0.00572
2005	-0.01141	0.03991	0.030559	0.03376	-0.053613	-0.000163	0.000007839	0.045981	0.005356	0.051182	-0.06130	-0.01012
2006	0.01749	-0.01377	0.019293	0.03877	-0.002349	0.000303	-.000071922	0.038787	0.009051	0.048069	-0.03355	0.01451
2007	0.04823	-0.03170	0.011719	0.01350	-0.071441	0.000500	-.000125846	0.007415	0.011160	0.018949	0.00147	0.02042
2008	-0.08125	0.07779	-0.004531	0.02506	-0.061640	0.000606	0.000175854	-0.009688	0.011357	0.002451	-0.15732	-0.15487
2009	-0.10137	0.02008	0.003517	0.02570	-0.096633	0.002569	0.000054836	-0.001798	0.010671	0.011496	0.14824	0.15974
2010	0.07678	0.11376	0.017061	0.03061	0.074507	-0.002201	-.000365170	0.049926	0.011662	0.059022	-0.04885	0.01017
2011	-0.05197	0.05458	-0.005722	0.01141	-0.043533	0.001906	-.000709101	-0.011862	0.012048	0.001383	-0.09310	-0.09172
2012	0.61394	-0.43188	0.010207	0.00719	-0.034733	-0.039602	0.009623106	0.016127	0.012223	-0.001628	-0.01544	-0.01706
2013	0.03337	-0.02063	0.006049	0.00277	-0.039878	-0.003072	0.000766934	0.005546	0.012836	0.016077	0.03543	0.05150
2014	-0.02737	0.05137	-0.003713	0.00427	0.035412	0.003002	-.002921314	-0.000212	0.012448	0.012316	-0.00608	0.00624

Total	0.71352	-0.033542	0.27665	0.45358	-0.40244	-0.023623	.005437071	0.49210	0.019502	0.49342	-0.39353	0.099889

Table-10

Annual Low Cost Carrier Cost Savings Due to Productivity Growth from Changes in Density, Firm Size, Movement Characteristics, and Technical Change, and from Changes in Input Prices

		Annual Changes in Firm Density, Size, and Movement Chars.				Annual Cost Savings (positive indicates savings)						
Year	Density Change	Size Change	Load Factor Change	Stage Length Change	Freight Share Change	Density	Firm Size	Moveme nt Chars.	Unexplained Technical Change	Total Factor Productivity	Input Prices	Total
1994	0.14662	0.06374	-0.011677	-0.02406	0.34515	0.016100	0.031657	-0.06147	-0.070075	-0.08379	0.12059	0.03681
1995	-0.15047	0.03036	-0.025547	-0.04837	-0.69918	-0.018974	0.014708	-0.07253	-0.063136	-0.13993	0.06464	-0.07529
1996	-0.10692	0.02581	-0.003373	-0.03171	0.68403	-0.015356	0.012132	-0.05720	-0.056404	-0.11683	0.11139	-0.00544
1997	-0.07797	-0.01879	-0.005055	-0.01564	-0.26353	-0.012137	-0.008519	-0.01216	-0.050807	-0.08363	0.00724	-0.07639
1998	0.19945	-0.05334	0.013063	-0.13355	-0.42122	0.036773	-0.022915	-0.07205	-0.048558	-0.10675	0.05584	-0.05091
1999	0.04887	-0.05687	0.028153	-0.01882	0.17253	0.010489	-0.022693	0.02754	-0.049323	-0.03399	0.09690	0.06291
2000	0.09278	-0.02578	0.011727	-0.14506	-0.36485	0.022870	-0.009320	-0.10259	-0.049782	-0.13882	0.06589	-0.07293
2001	0.18597	-0.10692	-0.017890	0.08284	-0.12037	0.047981	-0.034712	0.05940	-0.043803	0.02887	-0.01379	0.01508
2002	0.14210	-0.03832	-0.016205	0.01696	-0.11708	0.034271	-0.011374	0.00337	-0.032353	-0.00608	0.05185	0.04577
2003	0.42279	-0.03037	0.034246	0.06443	0.04111	0.097880	-0.008231	0.09148	-0.027155	0.15398	0.02968	0.18366
2004	0.05802	0.07143	0.021062	0.04118	0.03591	0.012960	0.018828	0.05524	-0.025974	0.06106	-0.09596	-0.03490
2005	-0.05965	-0.03857	0.027322	0.02201	-0.04175	-0.013284	-0.009842	0.04093	-0.024797	-0.00699	-0.03821	-0.04521
2006	0.08534	-0.00580	0.018291	-0.01044	-0.25219	0.019441	-0.001354	0.00849	-0.023468	0.00311	-0.02668	-0.02357
2007	0.05809	0.05114	0.001029	0.01351	-0.28034	0.013605	0.011266	0.02460	-0.020469	0.02900	0.01899	0.04799
2008	-0.00454	0.08292	0.003910	-0.04115	-0.00007	-0.001125	0.017955	-0.04326	-0.017337	-0.04377	-0.10353	-0.14729
2009	-0.13189	0.03492	0.032663	0.01070	-0.25589	-0.034734	0.007550	0.02122	-0.017726	-0.02369	0.06986	0.04618
2010	0.15639	-0.06355	0.030470	0.01744	-0.10752	0.041930	-0.013154	0.02328	-0.018410	0.03364	-0.05512	-0.02148
2011	0.09886	-0.02255	0.015599	0.01810	-0.07956	0.026718	-0.004259	0.02096	-0.016268	0.02716	-0.10811	-0.08096
2012	0.16539	-0.03081	-0.000201	0.01947	0.03213	0.044822	-0.005365	0.02042	-0.011506	0.04837	-0.01081	0.03756
2013	0.15202	0.02639	0.005168	0.02780	0.09147	0.040938	0.004367	0.02431	-0.005685	0.06393	-0.05998	0.00394
2014	0.02558	0.07451	0.016994	0.01002	-0.06078	0.006924	0.012340	0.00224	-0.002383	0.01912	0.05060	0.06972

Total	**1.50681**	**-0.030466**	**0.17975**	**-0.12433**	**-1.66199**	**0.37809**	**-0.020936**	**.002229833**	**-0.67542**	**-0.31603**	**0.23129**	**-0.08474**

Table-11

Annual "Other" Carrier Cost Savings Due to Productivity Growth from Changes in Density, Firm Size, Movement Characteristics, and Technical Change, and from Changes in Input Prices

Year	Density Change	Annual Changes in Firm Density, Size, and Movement Chars.				Annual Cost Savings (positive indicates savings)						
		Size Change	Load Factor Change	Stage Length Change	Freight Share Change	Density	Firm Size	Movement Chars.	Unexplained Technical Change	Total Factor Productivity	Input Prices	Total
1994	0.20537	-.04727	0.016735	0.28440	0.18241	0.036595	0.007465	0.13312	0.004263	0.18144	-0.10893	0.07250
1995	-.23657	0.13659	-0.009529	-0.01921	-0.04401	-0.046516	-0.016769	-0.01060	0.005949	-0.06793	-0.01017	-0.07810
1996	-.16706	0.24204	0.031309	0.11383	-0.07046	-0.035042	-0.029192	0.04984	0.009284	-0.00511	-0.16804	-0.17315
1997	0.35295	-0.25680	-0.009311	-0.08722	0.07190	0.076685	0.025897	-0.03286	0.009836	0.07956	0.12786	0.20742
1998	0.08931	-0.11271	-0.001611	-0.18538	-0.41073	0.016867	0.011173	-0.07850	0.006536	-0.04393	0.23955	0.19563
1999	0.15912	0.04040	0.009853	0.02842	-0.13794	0.028594	-0.003942	0.01617	0.006199	0.04702	-0.03512	0.01190
2000	-0.11409	0.13445	0.019833	0.01620	-0.24688	-0.021590	-0.011693	0.01254	0.007597	-0.01314	-0.04662	-0.05976
2001	0.01265	0.10280	0.024420	0.16450	0.14770	0.002673	-0.006736	0.06283	0.010558	0.06933	-0.12423	-0.05490
2002	0.15655	-0.06753	0.022924	0.04401	-0.04428	0.036539	0.001933	0.01332	0.011790	0.06358	0.05683	0.12041
2003	-0.18118	0.24838	0.007973	0.00008	-0.18573	-0.044214	-0.003928	-0.00115	0.012298	-0.03699	0.11690	0.07991
2004	0.03504	0.06392	0.019822	-0.04338	-0.25617	0.008693	-0.001441	-0.01483	0.014037	0.00646	0.04583	0.05229
2005	0.10563	0.06401	0.021145	0.00711	0.01313	0.026035	-0.001479	-0.00150	0.015103	0.03816	-0.12135	-0.08319
2006	-0.06628	0.04301	0.022892	0.00050	-0.11463	-0.016470	-0.000781	-0.00511	0.016620	-0.00574	-0.02004	-0.02579
2007	-0.25490	0.14745	-0.009351	0.05579	-0.15538	-0.064946	-0.001795	0.01376	0.019453	-0.03353	-0.15296	-0.18649
2008	-0.35489	0.12998	-0.032471	-0.11397	0.01520	-0.086548	-0.003698	-0.02428	0.022422	-0.09210	-0.21558	-0.30768
2009	0.29960	-0.28362	0.011056	-0.03503	-0.04594	0.065953	0.009869	-0.01002	0.023529	0.08933	-0.04092	0.04841
2010	-0.08514	0.03451	0.011740	0.07277	0.18289	-0.018602	-0.000314	0.02320	0.024076	0.02836	-0.00363	0.02473
2011	0.05581	0.14419	0.008639	-0.04570	-0.45072	0.012530	-0.000198	-0.01401	0.024984	0.02330	0.05715	0.08045
2012	0.21554	-0.34193	0.030496	0.07891	0.67042	0.049098	-0.009574	0.02242	0.023592	0.08554	0.04868	0.13422
2013	0.17869	0.03914	0.005586	0.12499	0.44768	0.042928	0.003153	0.02306	0.022060	0.09120	-0.01299	0.07821
2014	0.00556	0.02968	0.011150	-0.04229	0.22174	0.001347	0.002813	-0.00697	0.022866	0.02006	0.04333	0.06338

Total	**0.41171**	**0.49068**	**0.21330**	**0.41931**	**-0.20981**	**0.070608**	**-0.029236**	**0.17042**	**0.31305**	**0.52484**	**-0.32444**	**0.20040**

Appendix

Table A1: Variable Definitions and Data Sources	
VARIABLE	**SOURCE**
Cost and Input Shares	
Total Cost	(Operating Expense + Opportunity Cost of Capital)
Operating Expense	Form 41, Schedule P-6, Line 00360 – Total for the Year
Opportunity Cost of Capital	Net Property and Equipment x Before Tax Cost of Capital
Net Property and Equipment	Form 41, Schedule B-1, Line 16750 – Annual Average over 4 Qtrs
Before Tax Cost of Capital	Calculated by Authors – Data are from Aswath Damodaran, New York University, Damodaran Online: http://pages.stern.nyu.edu/~adamodar/ - these include: (1) historical U.S. Treasury Bond rates, before tax cost of debt for U.S. Airlines, effective tax rates for U.S. Airlines, U.S. Market Risk Premiums, historical betas for U.S. Airlines, historical debt and equity shares for U.S. Airlines – from 1993-1998, airline beta, tax rate, cost of debt, and equity/debt shares are unavailable – thus, 1999-2010 averages of these variables are used in calculating the cost of capital for 1993-1998.
Capital Share	(Opp. Cost of Capital+Rentals+Deprec.+Amort.)/Total Cost
Rentals	Form 41, Schedule P-6, Line 00310 – Total For the Year
Depreciation	Form 41, Schedule P-6, Line 00320 – Total For the Year
Amortization	Form 41, Schedule P-6, Line 00330 – Total For the Year
Fuel Share	Fuel/Total Cost
Fuel	Form 41, Schedule P-5.2, Line 51451 – Total For the Year
Labor Share	Salaries and Benefits/Total Cost
Salaries and Benefits	Form 41, Schedule P-6, Line 00140 – Total For the Year
Other Share	1 – Capital Share – Fuel Share – Labor Share
Input Prices	
Capital Price	(Opp. Cost of Capital+Rentals+Deprec.+Amort.)/ Air Hours
Air Hours	T-100 Segment, Air Time Minutes/60 --- Total for the Year
Fuel Price	Fuel/Gallons
Gallons	Form T-2, Aircraft Fuel Gallons – Total for the Year
Labor Price	Salaries and Benefits/Full Time Equivalent Employees
Full Time Equiv. Employees	From 41, Schedule P-1(a), FTEEmployees – Annual Average over 12 months
Other Price	(Total Cost – Opp. Cost of Capital – Rentals – Deprec. – Amort. – Fuel – Salaries and Benefits)/Ramp-to-Ramp Hours
Ramp-to-Ramp Hours	T-100 Segment, Ramp-to-Ramp Minutes/60 --- Total for the Year

Output Variables	
Revenue Passenger Miles	T1 Summary Data – Total for the Year
Revenue Ton-Miles (freight and mail)	T1 Summary Data – Total for the Year
Technological Characteristics	
Average Stage Length	T-100 Segment, Average Distance (weighted by number of departures) --- Average for the Year
Load Factor	Revenue Passenger Miles/Available Seat Miles
Available Seat Miles	T1 Summary Data – Total for the Year
Airports Served	T3 U.S. Air Carrier Airport Activity Statistics – Total Number of Airports
Time	Year – 1993
Costs and Input Prices are placed in 2005 prices using the GDP Implicit Price Deflator	