Low Cost Carrier Growth in the U.S. Airline Industry: Past, Present, and Future

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Abstract

This paper documents the growth of low cost carriers (LCCs) in the U.S. airline industry since 1990. By estimating simple probit models, we quantify the market characteristics which have influenced nonstop LCC entry in 351 city-pair markets over the past decade. We confirm that pre-entry market density is the single most important factor influencing LCC entry into a city-pair market. For each of the large-hub-and-spoke carriers, we quantify their past, present and future exposure to LCCs. In particular, we predict which markets currently not served by LCCs are the most likely to be entered in the future. Finally, we predict the proportion of network carrier revenue that may ultimately be exposed to nonstop LCC competition.

"We've finally reached the point, perhaps, where [low cost carrier] penetration may be fatal." – David Grizzle, Senior Vice President, Continental Airlines.[1]

1 Introduction

The growth of low cost carriers (LCCs) in the U.S. and elsewhere is arguably the single most important factor currently shaping the airline industry. While LCCs accounted for 7% of U.S. domestic passengers in 1990, their geographic scope was fairly limited, and for the most part, LCC service was synonymous with a single carrier, Southwest Airlines. In contrast, LCCs collectively accounted for nearly one-quarter of all domestic origin and destination (O&D) passengers during the first half of 2002.[2] And while Southwest is still by far the largest LCC, a number of other LCCs–namely AirTran, JetBlue, ATA and Frontier–have all been growing rapidly. The scope of LCC service, once limited to a handful of cities, now reaches virtually all corners of the country.[3]

The rapid growth of LCCs has commonly been cited as one of the primary causes of the financial crisis currently facing the large hub-and-spoke carriers.[4] Indeed, competition from LCCs has recently prompted two of the largest hub-and-spoke carriers, United and Delta, to announce that they will re-launch new, lower-cost sub-brands in markets where they face intense LCC competition. More generally, the continued growth of LCCs–and the declining market "dominance" of the large network carriers–represent an unfinished chapter of U.S. airline industry deregulation dating back to 1978. The evolving market structure–and the resulting impact on both fares and service–will depend critically on the direction of the competitive clash between LCCs and the major network carriers. Indeed, the impact of LCCs and the competitive responses they evoke from incumbent network carriers is likely to be the dominant theme in the airline industry for many years to come.

Despite their dramatic impact on the overall airline industry, LCCs have received surprisingly little attention in the current economics literature. A handful of studies (Morrison 2001, U.S. Department of Transportation 1996) have attempted to estimate the overall fare savings attributable to LCCs. Other studies (Dresner, Lin, and Windle 1996, Dresner and Windle 1999, Bennett and Craun 1993, Whinston and Collins 1992) have studied the route-level impact of LCC entry on incumbent carriers. More recently, Boguslaski, Ito, and Lee (2002) analyze entry patterns throughout the 1990's in Southwest Airlines' route system. Few in any studies however, have directly

[1] Source: "Low cost airlines put the crunch on biggest carriers," *The Wall Street Journal*, June 19, 2002.

[2] O&D passengers count travellers based on the starting and ending point of their journey, regardless of whether or not they make a connection.

[3] As summarized by Duane Woerth, President of the Air Lines Pilot Association (ALPA): "Ten years ago, except for Southwest in Texas, Arizona, and California, low-cost carriers were only a nuisance in most of the country; now they are a major force and at least three of them are well financed with strong balance sheets... [They] now pose a serious threat to network carriers and their futures." Source: *Report of Captain Duane Woerth to the 90th Executive Board of ALPA*, September 10-13, 2002.

[4] See, for example *Informational Brief of United Airlines, Inc.*, In the United States Bankruptcy Court For the Northern District of Illinois, December 9, 2002.

attempted to measure the degree of LCC penetration on the major network carriers or provide an estimate as to the potential for future LCC growth. Moreover, while lower costs are no doubt the primary source behind the success of LCCs, market selection has also played an important role. This paper aims to fill this gap in the literature by (a) documenting some stylized facts about the growth of LCCs since 1990, (b) estimating probit entry models to identify the characteristics of city-pair markets that have been the most influential in determining LCC entry and (c) estimating the potential for continued LCC expansion–in both the short and long term–and assessing what impact this may have on the major network carriers. We hope that this paper paves the paths for further research on this important industry development.

In general, we find–not surprisingly–that pre-entry passenger density (i.e., the number of passengers travelling in a market) has been the single most important factor in determining LCC entry over the past decade. And since the major network carriers also generate a substantial portion of their domestic revenue from these dense markets, their exposure to LCCs will continue to increase in the future. More specifically, we find that of the major network carriers, United Airlines currently faces the highest degree of exposure to nonstop LCC competition. Indeed, United currently generates over half of its domestic revenues in markets where it competes directly with LCCs and our analysis suggests that over two-thirds of United's domestic revenues could eventually be exposed to nonstop LCC competition. Three other carriers–Continental, Alaska and American–also face potential domestic revenue exposure exceeding 50%. Overall, our analysis suggests that LCC expansion is far from over: while LCCs currently offer nonstop service in markets accounting for 31.7% of the major network carriers' domestic revenue, this penetration rate could eventually exceed 55%, even under relatively conservative assumptions.

The remainder of this paper is organized as follows. Section 2 documents the growth of LCCs in the domestic airline industry since 1990 and provides some measures of past and current network exposure for the major hub-and-spoke carriers. Section 3 presents the estimation results of our probit entry models. Section 4 presents our network carrier vulnerability analysis. Brief conclusions are summarized in Section 5.

2 The Growth of Low Cost Carriers Since 1990

By any measure, the LCC segment of the U.S. domestic airline industry has grown dramatically since 1990. Table 1, for example, summarizes O&D passenger market shares for the largest LCCs as well as the major network carriers for the period 1990-2002.

Table 1: Market Share of Domestic Origin & Destination Passengers, 1990-2002

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
AirTran†				0.0	0.6	1.4	1.0	0.9	1.2	1.3	1.5	1.6	1.9
ATA	0.1	0.1	0.1	0.4	0.7	1.0	0.9	0.8	1.1	1.2	1.3	1.6	1.9
Frontier					0.0	0.2	0.3	0.3	0.3	0.5	0.6	0.6	0.8
JetBlue											0.3	0.8	1.3
Southwest	7.0	8.2	9.6	11.3	12.7	13.6	14.1	13.8	13.8	14.3	14.9	16.2	15.8
Other LCCs			0.2	1.9	2.4	2.3	2.8	2.4	2.2	2.2	2.0	2.1	2.0
Total LCCs	7.0	8.3	10.0	13.7	16.3	18.4	19.0	18.2	18.5	19.4	20.6	22.9	23.7
Alaska	1.8	1.9	1.9	2.0	2.6	2.9	3.1	3.0	3.1	3.0	2.9	3.0	3.2
America West	3.8	4.3	3.6	3.4	3.3	3.4	3.3	3.3	3.2	3.2	3.4	3.6	3.8
American	14.8	15.3	16.2	14.7	12.7	11.5	11.0	10.7	10.8	10.4	10.9	10.8	14.1
Continental	6.8	7.4	7.4	7.3	8.3	7.2	6.5	6.6	7.0	6.9	6.7	6.9	6.8
Delta	12.6	15.0	15.5	15.0	14.8	13.4	14.8	15.7	16.2	15.9	16.1	15.2	16.0
Northwest	7.1	7.3	7.5	7.3	7.1	7.4	7.5	7.6	7.0	7.6	7.6	7.6	7.6
TWA*	3.9	3.8	4.1	3.6	3.6	3.6	3.5	3.6	3.9	3.8	3.8	3.2	
United	11.5	12.8	12.7	11.8	11.2	11.9	11.9	12.1	13.2	12.7	11.7	11.0	10.2
US Airways	14.0	13.1	12.4	11.8	12.3	10.7	10.1	10.7	10.7	10.2	10.4	10.3	9.6
Other Carriers	16.6	10.8	8.8	9.5	7.7	9.7	9.2	8.7	6.6	6.9	5.9	5.6	5.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

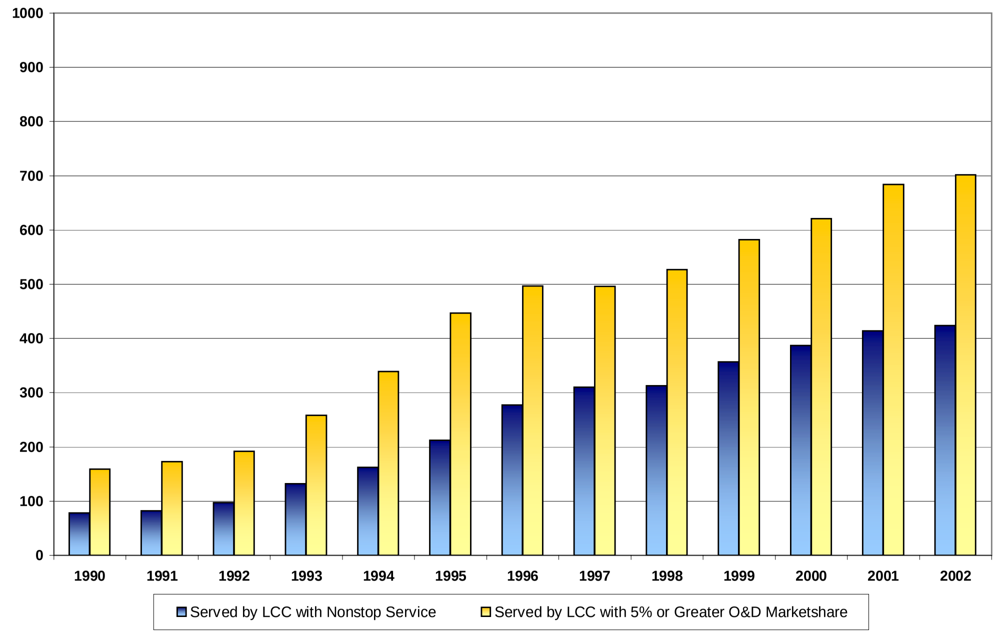
*Acquired by AMR Corporation in 2001. †Data for AirTran and ValuJet combined.
Source: U.S. DOT DB1A Database, 1990-2002. Data for 2002 is from the first and second quarters.

A number of observations from Table 1 are noteworthy. First, while Southwest was the only LCC with a national market share exceeding 1% in 1990, there are now four LCCs with domestic market shares exceeding 1%, with a fifth (Frontier) likely to be joining this group in the near future. Second, the combined market share of the LCCs has increased steadily each year since 1990 with the exception of 1997.[5] Finally, for the first time ever, Southwest Airlines was the largest domestic carrier in terms of O&D passengers during 2001 (data for 2002 is for the first six months).

It is well understood that LCCs typically enter city-pairs with high passenger density, since these markets allow them to exploit their comparative advantage in providing quick-turn, point-to-point service. Moreover, until recently, the networks of most LCCs were not large enough to generate a significant amount of "flow" or connecting traffic, and thus, the markets they entered typically needed to be dense enough to support nonstop service purely with local passengers. Figure 1 summarizes the number of the largest 1,000 domestic city-pair markets (which account for roughly 75% of all domestic O&D passengers) served by LCCs since 1990. While LCCs only served 78 of the largest 1,000 city-pairs in 1990 on a non-stop basis, this number had grown to 411 by the second quarter of 2002. If we also include all the markets that LCCs served on a connecting basis, the number of top 1,000 markets where a LCC carried at least 5% of the O&D passengers had increased from 159 in 1990 to 702 by the second quarter of 2002.

LCC entry into a market typically results in sharp drops in average fares, since LCCs are able to leverage their lower cost structure into substantially lower fares. Transportation Research Board

[5]The slight decline in LCC marketshare in 1997 followed the crash of ValuJet Flight 592 in May of 1996 which, resulted in increased FAA and media scrutiny on the operations of LCCs (Transportation Research Board 1999).



Notes: Nonstop service requires at least 5 weekly roundtrips. Source: U.S. DOT DB1A and T100 Databases.

Figure 1: LCC Presence In the Top 1,000 City Pair Markets

(1999), for example, analyzed routes which Southwest entered between 1990 and 1998 and found that on average, prices fell by 54%. Likewise, Lee and Luengo Prado (2002) found that even very low LCC presence on a route (i.e., 1% marketshare) results in a network carrier's prices being lower by 15%–23% compared to otherwise similar routes without LCC competition. In some markets, the effect of LCC entry on the incumbent carrier has been even more dramatic, as demonstrated by Figure 2. Shortly following the entry by Southwest into the Sacramento–Portland market in 1994, United Airlines, which had previously held a 90% share of passengers in this market, was forced to terminate nonstop service in the market altogether. While the Sacramento–Portland example is an extreme example of what can happen in a market following LCC entry, it nonetheless underscores why most network carriers have become increasingly concerned with their growing exposure to LCCs.

2.1 Network Carriers' Current Exposure to LCCs

Although the route systems of the LCCs collectively reach most areas of the U.S., the competitive impact of LCCs on the large hub-and-spoke carriers varies significantly. Table 2 summarizes the proportion of domestic passengers and revenues, by major network carrier, that are generated in markets exposed to nonstop LCC service. Specifically, we consider a market to be "exposed" to nonstop LCC service if a LCC served that market with at least five nonstop roundtrips per

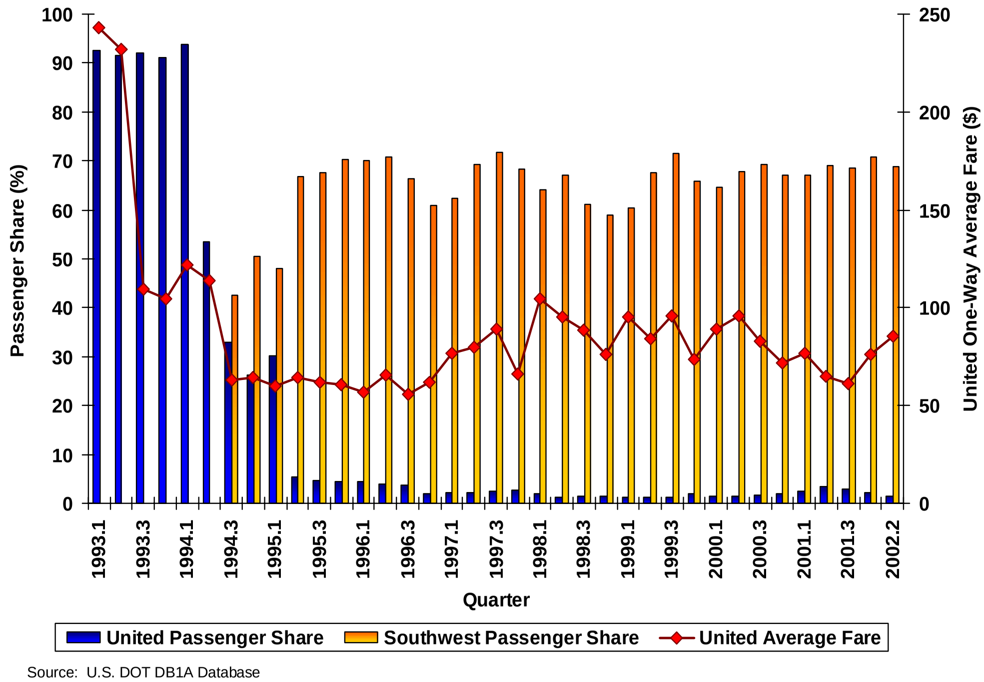


Figure 2: Southwest Entry into the Sacramento–Portland Market

week. Table 2 indicates that United's network is the most highly exposed, with slightly more than half of its domestic revenue generated in direct competition with LCCs, while Northwest's network–following the bankruptcy of Sun Country in 2001–is the least exposed (15.8%). Moreover, while none of the major network carriers had more than 5% of their domestic revenues exposed to nonstop LCC competition in 1990, five of the seven carriers now have more than one-quarter of their domestic revenues (and one-third of their domestic passengers) directly exposed to LCC competition. Since downward price pressure from LCCs does not necessarily require nonstop LCC service within a market, Table A.1 in the Appendix summarizes the percent of O&D passengers and revenues which are exposed to LCC competition, where we define a market to be exposed to LCC competition if there is a single LCC in that market with at least a 5% share of O&D passengers.

Table 2: LCC Nonstop Overlap with Major Network Carriers, 1990-2002

Proportion of Domestic Revenue Generated in Markets with Nonstop LCC Service	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Alaska	2.7	2.3	2.6	25.3	24.8	25.3	32.1	32.5	27.9	42.5	27.9	26.9	27.1
American	4.0	3.8	4.4	6.6	8.5	9.7	12.3	14.5	16.6	23.6	28.1	31.6	33.2
Continental	2.6	2.1	2.4	8.0	11.8	12.8	15.4	15.7	16.7	20.6	24.3	33.2	37.4
Delta	1.6	1.7	1.6	6.2	9.0	11.1	14.0	12.9	21.1	22.9	24.6	27.9	28.1
Northwest	1.5	1.0	1.1	1.5	2.7	4.0	8.2	12.3	12.2	28.1	28.6	24.7	15.8
United	3.0	4.6	5.6	12.0	17.0	19.5	28.5	30.4	31.2	36.6	37.4	42.6	50.9
US Airways	4.9	2.5	2.0	2.8	4.2	5.4	9.8	11.6	13.8	13.5	19.0	22.3	19.8
Proportion of Domestic O&D Passengers in Markets with Nonstop LCC Service	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Alaska	10.8	10.5	10.0	11.8	13.2	15.5	18.4	20.1	22.7	31.8	37.8	37.3	38.8
American	6.8	8.3	5.5	33.4	34.5	36.2	46.8	45.8	40.3	52.8	39.6	38.2	38.8
Continental	6.9	4.7	4.6	12.3	17.9	19.6	23.5	22.7	23.4	27.7	32.7	38.6	42.7
Delta	4.5	5.0	4.0	10.1	14.7	16.6	21.7	19.2	30.0	31.9	33.6	36.4	36.9
Northwest	4.5	3.4	3.0	3.3	5.3	7.6	13.8	18.3	19.1	32.8	33.1	29.4	20.6
United	8.9	15.0	13.0	20.9	25.9	33.0	43.1	44.0	43.1	47.6	47.7	48.7	54.2
US Airways	9.9	6.3	4.5	4.8	6.5	7.8	14.4	16.4	19.5	20.0	26.8	29.5	25.8

Source: U.S. DOT DB1A Database, 1990-2002. Data for 2002 is from the first and second quarters.
Notes: LCCs include Air South, Access Air, AirTran, American Trans Air, Eastwind, Frontier, JetBlue, Kiwi, Morris Air, National, Pro Air, Reno, Southwest, Spirit, Sun Country, ValuJet, Vanguard and Western Pacific.

It is important to note that the success of LCCs at penetrating the networks of the large hub-and-spoke carriers comes as somewhat of a surprise. Indeed, a number of studies (e.g., Borenstein 1989, Borenstein 1991, Ken Hendricks and Tan 1995) suggested that the large hub-and-spoke carriers were able to erect significant entry barriers at their hubs, largely preventing entry and allowing them to exercise market power on flights to and from their hubs. Other studies (Borenstein 1992) even suggested that powerful network economies may make competition in the post-deregulatory era "unworkable." Contrary to these previous dire predictions, LCCs have successfully penetrated almost every hub city. Table A.2 in the Appendix documents the market share of local travellers (i.e., excluding connecting passengers) at each of the hub cities of the major network carriers. In general–and as one would expect–the LCC's share of local passengers increases in larger cities, since these cities provide the base of population (i.e., potential density) required to offer point-to-point service in many markets. Thus, it should come as little surprise that smallest of the hub cities (in terms of population)–Cincinnati, Pittsburgh, Charlotte and Memphis–are also the cities with the lowest LCC penetration.

3 What Factors Have Influenced LCC Entry?

Having documented the growth of LCCs since 1990 and their penetration of major carriers' networks, we now turn our attention to identifying the market characteristics that have made entry attractive for LCCs over the past decade. To this end, we estimate probit models using a cross-section of markets. In particular, our unit of observation is a non-directional city-pair market. Thus, we assume that (a) passengers are in the same "market" regardless which direction they are travelling and (b) airports within the same metropolitan area are substitutes for one another.[6] The focus of our attention is on the five largest LCCs which are currently operating: Southwest, AirTran (formerly ValuJet), ATA, JetBlue and Frontier. As noted in Table 1, these five carriers accounted for roughly 85% of all O&D passengers travelling on LCCs in 2002.

Besides Southwest, the individual LCCs in our study have a relatively small number of market entries, which makes a carrier-specific probit estimation of entry rather fragile. Thus, we pool the entry information for all five LCCs together in one probit estimation. The dependent variable takes the value 1 if the market experienced an entry (or entries) by any of the five LCCs between 1992 and the third quarter of 2002, and takes the value 0 otherwise. We perform probit analyses using a broad range of market characteristics that we believe, *a priori*, may influence an LCC's decision to enter individual markets. While this approach is admittedly heuristic, it serves our purpose of exploratory analysis to identify the basic patterns of LCC entry. Moreover, our methodology allows us to analyze the overall penetration of LCCs–past, present and future–in the industry. Nevertheless, we should emphasize that our approach does not allow us to distinguish between the entry strategies of the five different LCCs in our study. Among the five LCCs in our study, at least three (Frontier, AirTran, and ATA) have primarily adopted a hub-and-spoke route system. Southwest's route structure–while possessing elements of connectivity–remains primarily a point-to-point network.

3.1 Data

Passenger and traffic data for this study is taken from the U.S. Department of Transportation's (DOT) OD1B Origin and Destination Survey, a 10% sample of all tickets reported by U.S. Scheduled Passenger Carriers. For the purposes of this study, we consider all domestic passengers in the data set travelling on round-trip and one-way itineraries with three or fewer coupons per directional leg. Data on flight frequencies and entry were taken from the DOT's T100 segment database.

Our base sample consists of the largest 2,500 domestic city-pair markets which together account for roughly 90% of all domestic O&D passengers. After excluding 69 markets that were already served by one of our five LCCs by 1991, we are left with 2,431 markets, each of which is between cities that are large enough to be classified as Metropolitan Statistical Areas (MSAs). We also excluded from our initial universe of markets those with distances greater then 3,000 miles or less

[6]Our airport groupings are: Washington, D.C. (BWI, DCA, IAD), San Francisco Bay Area (SFO, SJC, OAK), Los Angeles (LAX, BUR, LGB, SNA, ONT), Houston (IAH, HOU, EFD), Dallas (DAL, DFW), Chicago (ORD, MDW, GYY), Detroit (DET, DTW), New York City (LGA, JFK, EWR, HPN), Boston (BOS, PVD, MHT, ORH) and Miami (MIA, FLL).

than 100 miles, and those markets to, from or wholly within Alaska or Hawaii. An entry in our sample is defined as scheduling new nonstop service in a city-pair market. For consistency, we required that a LCC served a market for at least six months before we counted it as a valid entry and also, that the LCC offered at least five round-trips per week. Between 1992 and the second quarter of 2002, 351 of these top 2,431 markets experienced LCC entry, roughly half of which (189) were markets entered by Southwest. It is important to note that, while the focus of our analysis is on nonstop entry, some LCCs such as AirTran and Frontier operate hub-and-spoke networks with a significant amount of connecting passengers. While we recognize that our methodology largely abstracts from network considerations which may impact entry decisions, out framework should allow us to better understand how a variety of other market characteristics (i.e., demographic and competitive) influence LCC entry.

3.2 Exogenous Variables

Our data is constructed as cross section of markets and to mitigate the possibility of endogeneity in some of the variables (density and prices for example) we employ exogenous variables from the year 1990. The exogenous variables in our analysis are chosen based on their ability to impact the LCC's post-entry profitability. We group these exogenous variables into four broad categories: (1) route characteristics (i.e., market density, distance), (2) end-point city demographics (i.e. population, average per capita income), (3) hub effects, and (4) competition and concentration variables. We detail these variables below.

(1) Route Characteristics: It is well understood that LCCs have a comparative advantage in serving high density, short haul markets, since these types of markets are well suited to quick turn, point-to-point service. Our traffic density measure, **ln(density)**, is defined as the natural log of the average number of daily O&D passengers in the market carried by all carriers. We also include a set of several dummy variables that measures the nonstop distance between endpoint cities of the market. For example, **D(distance300)** takes the value one if the distance between the endpoint cities is greater than 300 miles and takes the value zero otherwise. **pricepm** is our price variable which is computed as the average price per mile (across all carriers) in the market. Since we are also controlling for distance (which has a strong negative influence on price per mile), we expect the estimated coefficient on **pricepm** to be positive.

(2) City Demographics: Major network carriers have traditionally generated a significant fraction of their revenue from business travellers, who tend to place more value (relative to leisure travellers) on non-price attributes of air service such as schedule convenience, frequent flyer programs, comfort and other amenities. In contrast, LCCs have traditionally catered to more price-elastic customers, many of whom are leisure travellers who are primarily interested in receiving the lowest possible fare. In the absence of the LCC option, many of these customers would likely choose to drive (in short haul markets) or not to travel at all. Thus, in order to predict post-entry profitability, it is important to include not only the actual density of a market (pre-entry demand size), but also some demographic variables which may influence a market's potential demand post-entry. **ln(maxpop)** and **ln(minpop)** are the larger and smaller of the endpoint city populations in natural log, which we assume to be a covariate of potential demand. Since we expect LCCs to attract a higher proportion of price-sensitive passengers, we also include **max(income)** and **min(income)**, the larger and the smaller of the average per capita incomes (measured in $1000s) respectively, at the endpoint cities of each market.[7] In addition, we attempt to capture a market's "vacation" status by including **D(sunbelt)**, a dummy variable that takes the value one if either of the endpoint cities (but not both) are in "sunbelt" states, and zero otherwise.[8] The **D(sunbelt)** variable attempts to take account of markets which are likely to be popular vacation markets in the winter periods. Since these markets attract a disproportionate amount of leisure travellers who often patronize LCCs, we expect **D(sunbelt)** to have a positive estimated coefficient.

(3) LCC and Major Network Hubs: Network considerations are often important factors in a carrier's entry decision, especially when they operate hub-and-spoke models (Sinclair 1995). Some LCC carriers, such as Frontier and AirTran, have developed hub-and-spoke networks and almost all of their market entries are to and from their primary hub cities. The selection of a hub city is difficult to predict since it involves complex strategic decisions. Thus, our analysis treats hub cities as exogenous information and concentrates on predicting the destination (i.e. "spoke") cities of a city-pair. **D(hublcc)** takes the value 1 if either of the end-point cities is a hub for any of our five LCCs. These LCC hub cities include: Atlanta (AirTran), Denver (Frontier), Chicago (ATA and Southwest), Baltimore/Washintgon, Las Vegas, and Phoenix (Southwest) and New York (JetBlue). Each of these hub cities has the characteristic that at least 50% of that carrier's destinations are served from its hubs (or quasi-hubs, in the case of Southwest). We expect the estimated coefficient on this variable to be strongly positive. In addition, we include another dummy variable **D(hubnet)** for hub cities in which the only airport is the hub of a major network carrier.[9] In general, we expect

[7]Our city demographic variables come from the Bureau of Economic Analysis, U.S. Department of Commerce.

[8]Our definition of "sunbelt" states follows Morrison (2001) and includes: California, Nevada, Arizona, Texas, Tennessee, Georgia, Louisiana, Alabama and Florida.

[9]Thus, **D(hubnet)**=1 for markets involving the following cities: Cleveland, Detroit, Cincinnati, Salt Lake City, Atlanta, Minneapolis, Memphis, Denver, Charlotte, Pittsburgh, Philadelphia and St. Louis. Although Detroit has a secondary airport (Detroit City Airport), its runway is generally considered to be too short (6,084 feet) to support

this variable to have a negative estimated coefficient for two reasons. First, some LCCs may try to avoid direct confrontations with the large network carriers. Indeed, there has been some anecdotal evidence of fierce price wars triggered by LCC entry into certain hub airports (Transportation Research Board 1999). Secondly, the hub airports of large network carriers may suffer from relatively higher congestion and delay problems (Brueckner 2002, Mayer and Sinai 2002) which may make typical low-cost operations–in particular, relying on quick-turn operations–impractical or less effective. In order to account for this congestion factor, we include **D(delay10)**, a dummy variable for the ten cities home to airports with the highest delay rates in 1990.[10] A common–albeit long term–institutional solution to prevalent delay problems is to build a second or, in some cases, a third airport within a metropolitan region. Since alternative airports are group together in our data, we include **D(multi)**, a dummy variable for multi-airport cities. We expect **D(delay10)** to have a negative estimated coefficient, while **D(multi)** is expected to have a positive estimated coefficient.

(4) Airport/Market Competition and Concentration: Competition within a market is a key determinant of post-entry profitability. Although post-entry competition is difficult to predict precisely, we include several variables that reflect the pre-entry state of competition and concentration in each market as our best predictor. In general, we expect markets with less intense competition pre-entry to be more profitable post-entry, and thus be more attractive candidates for LCC entry, all other things equal. We include **routehhi**, the Herfindahl-Hirschman Index (HHI) of O&D passengers for each market. A higher HHI indicates a more concentrated market structure and potentially less competitive environment. Moreover, we include **maxshare**, the largest share of all incumbent carriers on the route, a large value of which suggests the presence of a dominant incumbent. Finally, we include **max(cityhhi)** and **min(cityhhi)**, which are the HHIs (in terms of local O&D passengers) at the endpoint cities, sorted from the largest to smallest.

Summary statistics for the variables described above for the full sample of routes, as well the subsets of routes with and without LCC entry, are presented in Table 3 below.

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the needs of most large carriers.

[10] These cities include: New York, Chicago, San Francisco, Atlanta, Boston, Minneapolis, St. Louis, Denver, Dallas and Detroit. Source: *FAA Aviation System Capacity Plan, 1991-92.*

Table 3: Dataset Summary Statistics

	All Markets		No LCC Entry		LCC Entry	
Variable	Mean	(Stdev.)	Mean	(Stdev.)	Mean	(Stdev.)
D(lccentry)	0.144	(0.352)	0.000	(0.000)	1.000	(0.000)
ln(density)	4.503	(1.093)	4.295	(0.939)	5.734	(1.130)
pricepm	0.237	(0.151)	0.236	(0.150)	0.243	(0.152)
D(delay10)	0.360	(0.480)	0.348	(0.476)	0.436	(0.497)
D(dist300)	0.904	(0.294)	0.903	(0.296)	0.909	(0.288)
D(dist600)	0.684	(0.465)	0.694	(0.461)	0.627	(0.484)
D(dist1200)	0.305	(0.461)	0.322	(0.467)	0.208	(0.406)
D(dist1800)	0.144	(0.352)	0.158	(0.365)	0.066	(0.248)
D(dist2400)	0.028	(0.166)	0.031	(0.174)	0.011	(0.106)
ln(maxpop)	14.913	(0.838)	14.894	(0.835)	15.028	(0.849)
ln(minpop)	13.535	(0.658)	13.472	(0.631)	13.906	(0.691)
max(income)	16.728	(1.955)	16.711	(1.961)	16.824	(1.922)
min(income)	14.225	(1.472)	14.155	(1.481)	14.637	(1.347)
D(hubnet)	0.352	(0.478)	0.359	(0.480)	0.311	(0.463)
D(hublcc)	0.221	(0.415)	0.180	(0.385)	0.462	(0.499)
D(multi)	0.344	(0.475)	0.333	(0.471)	0.410	(0.493)
max(cityhhi)	2.881	(1.145)	2.945	(1.163)	2.502	(0.950)
min(cityhhi)	1.736	(0.568)	1.761	(0.579)	1.592	(0.475)
routehhi	4.430	(2.087)	4.466	(2.109)	4.218	(1.939)
maxshare	0.524	(0.222)	0.530	(0.221)	0.490	(0.221)
D(sunbelt)	0.418	(0.493)	0.405	(0.491)	0.496	(0.501)
N	2,431		2,080		351	

3.3 Estimation Results

We are interested in investigating the factors which have been the most influential in determining LCC entry over the past decade. Although our cross-sectional methodology enables us to identify general characteristics of markets which LCCs have found attractive, pooling all markets assumes that the effects of our exogenous variables is more or less consistent across all market types. Advances in aviation technology, however, have only recently made longer haul markets available to many LCCs given their traditional focus on a single aircraft-type fleet. Early models of the Boeing 737 for example, which Southwest Airlines uses exclusively, did not have the range to fly transcontinental flights. Thus, we estimate two sets of probits. The first set pools markets of all distances together; the second set segments the data into short haul (less than 600 miles), medium haul (600-1200 miles) and long haul (1200 miles or greater) markets.

3.3.1 Combined Sample Results

Table 4 summarizes the probit results from our combined sample estimation.

Table 4: Probit Estimation - Combined Distance Sample

Variable	Coefficient	(StdErr.)	$\partial P/\partial X$
constant	8.070†	(1.933)	
ln(density)	1.315†	(0.078)	0.122
pricepm	3.718†	(0.639)	0.345
D(delay10)	-0.262*	(0.132)	-0.023
D(dist300)	1.129†	(0.221)	0.052
D(dist600)	0.203	(0.141)	0.018
D(dist1200)	0.002	(0.132)	0.000
D(dist1800)	-0.091	(0.188)	-0.008
D(dist2400)	-0.555	(0.417)	-0.033
ln(maxpop)	-0.710†	(0.104)	-0.066
ln(minpop)	-0.253†	(0.093)	-0.023
max(income)	-0.060*	(0.028)	-0.006
min(income)	-0.121†	(0.038)	-0.011
D(hubnet)	-0.525†	(0.135)	-0.043
D(hublcc)	0.722†	(0.112)	0.095
D(multi)	-0.315	(0.166)	-0.027
max(cityhhi)	-0.077	(0.056)	-0.007
min(cityhhi)	-0.247*	(0.107)	-0.023
routehhi	-0.045	(0.034)	-0.004
maxshare	0.161	(0.293)	0.015
D(sunbelt)	0.036	(0.102)	0.003
N		2,431	
Log Likelihood		-591.76	
Pseudo R^2		0.4104	
Observed P		0.144	
Predicted P		0.044	
% of entry predictions correct		69.5	
% of actual entries predicted		46.7	

For dummy variables, $\partial P/\partial X$ measures the change from 0 to 1.
*Significant at the 5% level. †Significant at the 1% level.

The overall fit of the model for the combined sample is moderately good despite the fact that the model contains no carrier specific variables. Indeed of the 351 markets that were entered by LCCs during the sample period, the model predicted 167 correctly, or roughly 47%. Moreover, of the markets for which the model predicts entry (i.e., estimates an entry probability of 50% or greater), approximately 70% were actually entered.

As expected, market density is by far the most powerful predictor of LCC entry. In particular, a 1% increase in density increases the probability of entry by .12%. Given the large variability of the density variable (the minimum is 21.95 and the maximum is 19,903.42), the magnitude of this effect somewhat overwhelms most other influences. Thus, our estimation results confirm the general belief that LCC entry closely targets markets with high traffic density. In addition, the strongly positive and significant coefficient on **pricepm** indicates that LCCs also concentrate their entry in markets where incumbent carriers were earning relatively large price markups. One natural question is how continued LCC entry will be distributed across the revenue bases of large network carriers–a question which we will address in Section 4.

The estimated coefficients on the distance dummies show, not surprisingly, that LCCs have typically entered markets longer than 300 miles. However, the coefficients do not show strong concentrations of LCC entry in any particular distance segment beyond 300 miles. Indeed, LCC entry has been widely distributed across markets with distance ranges between 300 miles and 2,400 miles, with the most popular range being between 1,200 and 1,800 miles. This is somewhat surprising since the largest LCC, Southwest, has traditionally been known to focus on short haul markets. However, while Southwest's average flight length is still very short (537 miles), the average length of the markets it has entered has almost tripled since 1991. It is also worth noting that the majority of markets entered by the fastest growing LCC–JetBlue–have been primarily long-haul markets.

The dummy variable for the LCC hub cities, **D(hublcc)**, is positive and significant, but this is largely by construction. Indeed, we include this variable primarily to control for the concentration of LCC entries through their hub cities or central network nodes. Instead, we are more interested in the LCCs' choice of their destinations (i.e. spokes). While the density variable has extremely powerful predictive power, the city demographic variables (**ln(maxpop), ln(minpop), max(income), min(income)**) tend to help pick up some of the exceptions. Thus, population as well as the per capital average income have a negative influence on LCC entry probability, which is consistent with the general observation that some LCCs (in particular Southwest) have tended to avoid many large metropolitan areas and large business centers in favor of secondary airports within driving distance. For example, Southwest serves the New York City metropolitan area via MacArthur Airport in Islip, Long Island.

The presence of network hubs (**D(hubnet)**) reduces LCC entry probability by 4.3%, confirming our belief that in general–LCCs prefer to serve markets which involve non-hub cities. We should emphasize that our **D(hubnet)** variable focusses only on those cities where the only airport is a hub of a major network carrier. Thus, while United and American both operate hubs at Chicago O'Hare, Southwest has been able to expand into many markets from Chicago via its service at Midway airport. Nevertheless, even though we find, in general, that LCCs prefer to avoid major carrier hub airports, it is important to emphasize that at least two LCCs (AirTran and Frontier) have been very successful in establishing and expanding the base of their operations directly at major hub airports (Atlanta and Denver).[11] The negative and significant estimated coefficient on **D(delay10)** also confirms our belief that LCCs prefer to avoid congested airports, as these airports tend not to be conducive to quick-turn service.[12] The estimated coefficient on **multidum** however,

[11]It should be noted, however, that among the single-airport hub cities, Atlanta and Denver are among the largest in terms of O&D passenger base.

[12]For example, when Southwest discontinued service from San Francisco International Airport (SFO) in March 2001, CEO Herb Kelleher stated "San Francisco International Airport operation has not been profitable for a considerable period of time; operation into and out of that airport produces a disproportionate number of flight

had a negative and insignificant coefficient. We suspect that this effect is difficult to distinguish from the hub-avoidance effect we identified earlier, as LCCs–in general–have large presences in most cities with secondary airports (i.e., Dallas, Houston, Chicago, Washington, San Francisco and Los Angeles).

With the exception of **min(cityhhi)**, none of our market concentration variables were significant, suggesting pre-existing competitive factors do not tend to play an important role in an LCC's decision to enter a market. Instead, the primary drivers appear to be demographic in nature. It is also possible that actual market structure details are less important than the pre-entry price markups as measured by **pricepm**, which was significant and as expected, had a positive estimated coefficient. The estimated coefficient on **D(sunbelt)** had the expected positive sign, but it was insignificant. This may reflect the overall change in the types of markets LCCs now serve to include not only leisure markets, but also many of the primary business markets.

3.3.2 Split Distance Results

We now repeat the same probit analysis from Section 3.3.1 using the split-distance samples. Table 5, which summarizes the number of LCC entries by year and distance, motivates our distance-based market segmentation. The table shows early LCC entries were concentrated in the short and medium-haul markets. It is important to note that the early period of our data primarily reflects entries by Southwest, and to a lesser extent, ATA and AirTran/Valujet; Frontier enters our dataset in 1995 and JetBlue enters our dataset in 2000. As noted by Boguslaski, Ito, and Lee (2002), Southwest's entry strategies in the early and middle parts of the 1990's focused first on short-haul markets (largely within California and Texas) and subsequently on medium-haul markets, often aimed at North-South vacation travellers. Only recently has LCC entry into long-haul markets become typical. Indeed, the recent shift in entry strategies by LCCs to target transcontinental markets where the major network carriers have long operated without LCC competition is likely to become the focus of much industry attention in the years to come.

delays rippling across our system." *Sacramento Business Journal*, January 22, 2001.

Table 5: LCC entries - By Year and Distance Segments

Year	Total LCC Entries	Short-Haul < 600 miles	Medium-Haul 600–1200 miles	Long-Haul > 1200 miles
1992	11	8	3	0
1993	11	3	7	1
1994	39	20	15	4
1995	56	34	21	1
1996	55	16	34	5
1997	30	12	11	7
1998	26	10	7	9
1999	20	4	10	6
2000	35	7	14	14
2001	33	9	10	14
2002	35	8	15	12
Sum	351	131	147	73

Probit estimation results for each three distance segments are reported in Table 6. The dominating effect of market density seen in the full sample remains in each of the split-distance probits. The estimated coefficient for **pricepm** remains positive and significant in the short and medium haul markets, but becomes insignificant in long haul markets. This is consistent with the common understanding (U.S. General Accounting Office 1999) that prices in longer haul markets tend to gravitate more to competitive levels since many of these markets are spoke-to-spoke markets with competition from multiple hubbing carriers. As expected, the estimated coefficient for **D(hublcc)** is positive and significant in each of the three samples. The estimated coefficient for **D(hubnet)**, however, becomes insignificant in short-haul markets. This may reflect–in part–the fact that at the network hub cities where there has been the most significant LCC entry (Atlanta and Denver), the average market distance for the hubbing LCCs (AirTran and Frontier) has tended to be relatively short.

The negative effects of the city demographic variables (**ln(maxpop), ln(minpop), max(income), min(income)**) tend to be the strongest in the short-haul markets. This is likely a result of the gradual expansion of LCCs throughout the decade into the Northeast part of the country (first by Southwest, and more recently by JetBlue and AirTran). As noted earlier, Southwest's expansion outside of its traditional California and Texas markets beginning in the early 1990's also coincided with a marked increase in the average distance of its new markets. Likewise, JetBlue, which began service in 2000, has the longest average route distance of any of the LCCs. More generally, the fact that the income variables (and the **D(sunbelt)** variable in medium and long haul markets) do not tend to be significant suggests that LCCs should no longer be considered as niche carriers catering only to leisure passengers. To the contrary, there is substantial anecdotal evidence which now suggests that LCCs have become increasingly popular among businesses seeking to lower travel costs.[13]

In summary, both our combined and split distance samples confirm that LCCs target extremely dense markets with above average prices (compared to markets of similar distance). Contrary to the common perception, LCC entry is no longer limited to only short and medium haul markets–a feature which characterized LCC entry during the 1980's and first part of the 1990's when LCC service was synonymous with Southwest.

[13]See, for example, "Sept. 11, Wobbly Economy Change Corporate Attitudes about Travel Costs," *St. Petersburg Times*, August 11, 2002.

Table 6: Probit Estimation Results - Split Distance Samples

	Short-Haul Markets $\leq$ 600 miles			Medium-Haul Markets 600–1200 miles			Long-Haul Markets $>$ 1200 miles		
Variable	Coef.	(Std. Err.)	$\partial P/\partial X$	Coef.	(Std. Err)	$\partial P/\partial X$	Coef.	(Std. Err.)	$\partial P/\partial X$
constant	15.42†	(3.30)		7.06*	(3.65)		9.50*	(4.60)	
ln(density)	1.22†	(0.12)	0.15	1.64†	(0.16)	0.16	1.25†	(0.20)	0.03
pricepm	2.08†	(0.80)	0.26	5.67†	(2.02)	0.55	9.02	(5.58)	0.20
D(delay10)	-0.14	(0.24)	-0.02	-0.32	(0.24)	-0.03	-0.54	(0.29)	-0.01
ln(maxpop)	-1.00†	(0.20)	-0.12	-0.71†	(0.18)	-0.07	-0.76†	(0.21)	-0.02
ln(minpop)	-0.53†	(0.16)	-0.07	-0.23	(0.17)	-0.02	-0.10	(0.24)	0.00
max(income)	-0.05	(0.05)	-0.01	-0.04	(0.04)	0.00	-0.08	(0.07)	0.00
min(income)	-0.01	(0.07)	0.00	-0.17†	(0.06)	-0.02	-0.08	(0.09)	0.00
D(hubnet)	0.01	(0.22)	0.00	-0.96†	(0.24)	-0.08	-1.02†	(0.33)	-0.02
D(hublcc)	0.91†	(0.23)	0.17	0.76†	(0.21)	0.11	0.99†	(0.23)	0.04
D(multi)	0.38	(0.30)	0.06	-0.96†	(0.29)	-0.08	-0.21	(0.35)	0.00
max(cityhhi)	-0.26†	(0.09)	-0.03	0.12	(0.09)	0.01	0.32	(0.19)	0.01
min(cityhhi)	-0.29	(0.15)	-0.04	-0.05	(0.19)	0.00	-1.04*	(0.42)	-0.02
routehhi	0.00	(0.04)	0.00	-0.09	(0.07)	-0.01	-0.70†	(0.22)	-0.02
maxshare	0.52	(0.37)	0.06	0.35	(0.61)	0.03	1.03	(1.46)	0.02
D(sunbelt)	0.48*	(0.20)	0.08	-0.07	(0.19)	-0.01	-0.14	(0.21)	0.00
N			768			921			742
log Likelihood			-212.608			216.197			-128.260
Pseudo R^2			0.394			0.466			0.462
Observed P			0.171			0.160			0.098
Predicted P			0.064			0.047			0.008
% of entry predictions correct			44.3			57.1			43.8
% of actual entries predicted			69.9			75.0			68.1

Each sample contained two distance dummy variables, but their coefficients are suppressed.
For dummy variables, $\partial P/\partial X$ measures the change from 0 to 1.
*Significant at the 5% level. †Significant at the 1% level.

4 Future LCC Growth and Network Vulnerability

Continued growth by LCCs is likely to be the primary driving force behind the future evolution of the deregulated U.S. airline industry in the coming years. Indeed, most Chief Executives at the large hub-and-spoke carriers have come to realize that their very survival will depend on their ability to compete directly with LCCs. For example, while unveiling its new lower-cost subsidiary in November 2002, Delta CEO Leo Mullin stated that "low-fare carriers represent a real threat to Delta - substantially more than that from other hub and spoke competition."[14] Likewise, American Airlines' Chief Executive Don Carty recently asserted that "Our major competition over the last 15 years was other people doing the same things we do. That's not the case anymore."[15]

In light the undeniable competitive impact that LCCs have had on legacy carriers and the estimation results presented in Section 3, three obvious questions come to mind. First, which markets currently not served by LCCs does our model predict as being the most likely for future entry? Second, based on the markets our model predicts as the most likely for future entry, which of the large network carriers are most vulnerable to continuing LCC expansion in the near term? Finally, based on the markets entered by LCCs thus far, what can we say about the potential degree of penetration which LCCs might ultimately have in the U.S. airline industry? In this section, we attempt to answer these three questions.

Table 7 summarizes the 20 domestic markets currently not served by LCCs (on a nonstop basis) that our model assigns the highest probability of LCC entry. It also reports, for each of these markets, the largest incumbent carrier, the 2000 passenger revenue the incumbent carrier generated in that market, and the percentage of the incumbent carrier's total domestic revenue generated in that market.

[14]Source: "Delta Air Lines Announces New Low-Fare Subsidiary," Delta Air Lines Press Release, November 20, 2002.

[15]See "American Airlines to Retrench in Bid to Beat Discount Carriers," *The Wall Street Journal*, August 13 , 2002.

Table 7: Top Predicted Entry Markets

Rank	Market	Predicted Entry Probability	Incumbent Carrier	Incumbent Vulnerable Rev. ($millions)	Incumbent % of Carrier's Dom. Revenue
1.	New York - Boston	98.0%	Delta	138.0	1.2%
2.	Seattle - Portland	96.5%	Alaska	24.7	1.7%
3.	New York - Washington, D.C.	96.1%	Delta	106.0	0.9%
4.	Seattle - Los Angeles	90.9%	Alaska	171.0	11.7%
5.	Dallas - New York	85.6%	American	257.0	2.7%
6.	Oklahoma City - Las Vegas	82.7%	American	4.6	0.0%
7.	Tucson - Phoenix	80.0%	America West	1.1	0.1%
8.	Portland - Los Angeles	76.6%	Alaska	80.3	5.5%
9.	Miami - Tallahassee	76.5%	Delta	9.4	0.1%
10.	Chicago - New Orleans	74.1%	American	16.9	0.2%
11.	Seattle - San Diego	74.0%	Alaska	52.6	3.6%
12.	San Antonio - New Orleans	73.6%	Southwest	6.0	0.1%
13.	Dallas - Las Vegas	73.5%	American	31.0	0.3%
14.	Dallas - Phoenix	73.2%	American	54.3	0.6%
15.	Dallas - Washington, DC	72.6%	American	173.0	1.8%
16.	Phoenix - Minneapolis	71.8%	Northwest	52.8	0.9%
17.	New York - Houston	71.1%	Continental	209.0	3.8%
18.	Orlando - Las Vegas	71.0%	Delta	15.7	0.1%
19.	Milwaukee - Las Vegas	70.5%	Sun Country*	14.9	7.5%
20.	Tallahassee - Orlando	70.1%	US Airways	3.9	0.1%

*Sun Country declared bankruptcy in 2001. The incumbent carrier is currently Midwest Express.

A number of interesting observations can be drawn from Table 7. Two of the top three markets that our model predicts will be entered by LCCs are Northeast "Shuttle" markets which are both extremely dense and where the high proportion of business traffic results in above prices (per mile). Many of the airports serving these cities also tend to be among the most highly congested in the country or are governed by the High Density Rule–factors which may have thus far discouraged direct entry into the most popular airport-pairs (i.e., BOS-LGA and LGA-DCA) which are currently dominated by the incumbent Shuttle carriers.[16] In some respects however, there has already been peripheral LCC entry into these markets via Southwest's neighboring service to Baltimore and Providence from Islip, Long Island (note that we did not include Islip as one of the airports in our New York City grouping).

Table 7 also illustrates the impact–to some extent–that the Wright/Shelby Amendments have had on entry into Dallas. The Wright and Shelby Amendments prohibit carriers from serving Dallas' Love Field (DAL) and any airport outside of Texas, Louisiana, Arkansas, Oklahoma, New Mexico, Mississippi and Alabama with aircraft of 59 seats or greater. Indeed, four of the top fifteen predicted entry markets are to and from Dallas and these four markets collectively accounted for

[16]For the period of analysis in our paper, the High Density Rule (HDR) applied to Chicago O'Hare, Washington National (DCA), and New York's La Guardia (LGA) and JFK airports. In order to operate at these airports, carriers must possess take-off and landing "slots." Although many slots were initially grandfathered, a secondary market allows them to be bought, sold and leased. The HDR was lifted at ORD on July 1, 2002.

nearly half a billion dollars in revenue for American during 2000 (or roughly 5.5% of American's domestic revenue). Southwest, which is headquartered at Dallas' Love Field however, is precluded from serving any of these market due to the Wright/Shelby Amendments. While Southwest entry into any of these four markets is unlikely, one would expect newer LCCs such as JetBlue to enter these markets via service to Dallas-Ft. Worth airport. Indeed, given JetBlue's presence at both JFK and Washington-Dulles airports, entry into the Dallas-New York and Dallas-Washington markets seems all but a matter of time.

Finally, four of the top eleven markets are West Coast markets where the incumbent carrier is Alaska Airlines. Moreover, each of the cities which comprise these markets (Seattle, Portland, Los Angeles and San Diego) is currently served by Southwest. Together, these four markets account for roughly 20% of Alaska's domestic revenue, indicating that Alaska is highly exposed to potential LCC (in particular Southwest) entry.

4.1 Future Network Vulnerability

Having estimated the markets which LCCs are most likely to enter in the future, we now turn our attention to the implications of these predictions on the major network carriers. Every major carrier has already experienced the impact of low cost carriers in some part of their network. As LCCs expand into the long-haul markets where network carriers have previously operated without direct competition from LCCs, major network carrier exposure to LCCs will almost certainly intensify.

We are interested in measuring the vulnerability of the major network carriers to future LCC expansion. In particular, our goal is to predict the proportion of current network carrier revenue that is likely to be exposed to future nonstop competition from LCCs. We apply two basic approaches for estimating future network vulnerability. The first approach focuses on estimating short term vulnerability by computing the incremental revenue exposure that would result from LCCs entering all of the 100 most likely (according to our model) predicted markets. Based on the current growth rates of LCCs, this would represent incremental network exposure over the next 2-4 years. Our second approach attempts to estimate the long term (or steady state) exposure potential of the major network carriers based a historical density criteria.

At the outset, we stress that these predictions are likely to be the lower bound for the actual exposure of network carriers to LCC expansion. Indeed, our predictions underestimate the likely impact for a number of reasons. First, while entry by a LCC on a nonstop basis clearly poses the greatest threat to an incumbent carrier's revenues, connecting service on LCCs also has the effect of significantly depressing fares, especially leisure fares. Since the number of connecting markets grows exponentially as new cities are added to a LCC's route system, the revenue impact from connecting competition increases in a non-linear fashion as LCCs add additional cities to their networks. Finally, our airport groupings are based largely on those in the *Official Airline Guide*, which tend to understate the true catchment area of LCCs' service, especially for price sensitive leisure travellers who may be willing to drive significant distances to fly at the lowest available fare (Morrison 2001). For example, our analysis does not consider the impact of Southwest's flights to and from Louisville on Delta's Cincinnati markets, even though many travellers living in Cincinnati may be willing to drive two-hours to Louisville to take a Southwest flight.

4.1.1 Short Term Network Vulnerability

In order to develop our short term predictions of network vulnerability, we begin by defining some notation. Denote N as the set of all (i.e., not the top 2,500) possible domestic city-pair markets and r_i^k as the passenger revenue generated by carrier k in market $i \in N$ during 2000. Then, $R^k = \sum_i^N r_i^k$ denotes carrier k's total domestic passenger revenue. Finally, denote $\omega_i^k = \frac{r_i^k}{R^k}$ as the proportion of carrier k's domestic passenger revenue generated in market i. Define P^l as the vector of predicted entry probabilities by LCCs with typical element p_i^l. The top twenty of these probabilities are listed in Table 7. Denote $p_{(n)}^l$ as the nth order statistic of P^l.[17] We define $L \subseteq N$ as the subset of markets such that $P_L^l = \{p_{(N)}^l, p_{(N-1)}^l, \ldots, p_{(N-|L|+1)}^l\}$. That is, L denotes the set of markets with the $|L|$ largest entry probabilities, where $|L|$ denotes the cardinality (i.e., the number of elements) in the set L. Define carrier k's *vulnerability* as:

$$V_L^k = \sum_{i \in L} \omega_i^k$$

That is, V_L^k measures the proportion of carrier k's domestic passenger revenues that are generated by the $|L|$ most likely markets which our model predicts LCCs will enter. Table 8 summarizes the network vulnerabilities of the major network carriers for the one hundred most likely markets that LCCs will enter ($|L|$=100), according to our model.

TABLE 8: SHORT TERM NETWORK VULNERABILITY

	Current Revenue Exposure (As of 2002)	V_{100}^k: Incremental Future Revenue Exposure Predicted
Alaska	27.1%	24.3%
American	33.2%	15.0%
Continental	37.4%	20.5%
Delta	28.1%	10.2%
Northwest	15.8%	7.6%
United	50.9%	3.7%
US Airways	19.8%	6.4%

[17] That is, $p_{(1)}^l$ denotes the smallest probability of entry and $p_{(N)}^l$ denotes the highest probability of entry.

Table 8 demonstrates that of the major network carriers, Alaska, American and Continental are likely to face the greatest degree of new market penetration over the next few years. In contrast, United, which has thus far faced the highest degree of direct revenue exposure appears to face a much smaller level of incremental exposure over the next few years. We should point out, however, that United would still face the highest degree of direct revenue exposure (existing plus incremental) even if the predictions in Table 8 were borne out in their entirety.

4.1.2 Long Term Network Vulnerability

Having estimated the short term revenue exposure as our lower bound, we now attempt to estimate the upper bound, or long term potential revenue exposure. To this end, we take advantage of the fact that pre-entry density has been the single most important criterion–by far–driving LCC entry decisions over the past decade.

Table 9 stratifies all domestic U.S. markets into 9 different bins according to their passenger densities in 1990 (i.e., "density bins"). Column (c) of Table 9 tabulates the number of entries, by density bin, of the markets entered by LCCs between 1992 and 2002. Since density increases sharply following LCC entry, we consider the density of a market entered by an LCC two years prior its entry and the figures in column (d) exclude the markets which were already served by LCCs prior to 1992. Column (e) computes the entry frequency by density bin and column (f) reports the cumulative proportion of 2000 industry revenue generated by density bin. For example, column (f) indicates that in 2000, fully 82% of domestic industry passenger revenue was generated in markets which carried 76 or more passengers per day (bin 5).

Not surprisingly, Table 9 clearly demonstrates an overwhelming preference by LCCs to select markets in the high density bins; LCCs entered roughly three-quarters of the markets which generated more than 1,000 daily passengers (bin 9) and over half of the markets generating between 501 and 1000 daily passengers (bin 8). In contrast, LCC penetration drops sharply once market density falls below 250 passengers per day (bins 1–6).[18]

[18] The five entries which Table 9 indicates were in very thin (i.e., bin 1) were Southwest entries into markets to and from Islip, which prior to entry, were essentially unserved.

Table 9: Density Stratification of LCC Entries, 1992-2002

Density Bin (a)	Passengers Per Day (b)	Number of LCC Entries (c)	Total Number of Markets in Bin (1990) (d)	Percent Entered (e)	Cumulative Industry Revenues (2000) (f)
1	≤ 5	5	26,948	0.0	100.0
2	6–25	13	4,645	0.3	96.8
3	26–50	12	1,227	1.0	90.4
4	51–75	9	525	1.7	85.5
5	76–100	26	284	9.2	82.0
6	101–250	83	573	14.5	79.3
7	251–500	84	273	30.8	68.6
8	501–1000	64	120	53.3	57.6
9	1001+	64	85	75.3	43.5

Source: U.S. DOT DB1A and T100 Databases, 1990-2002.

While it might be reasonable to expect LCCs to eventually enter all of the markets in the 8th or possibly 7th density bin and above, the chances that LCCs will eventually enter all (or even the majority) of markets in the 3rd, or even 4th density bin would appear remote. What is more difficult to predict is the eventual LCC penetration rate into markets falling into the 5th and 6th density bin (76-250 passengers per day). While many of these markets are unlikely to generate enough local traffic to support daily nonstop service by an LCC, entry into these routes may still be feasible depending on the amount of flow traffic they can generate. Thus, depending on how the network breadth of the LCCs evolve, many of these markets may also support LCC entry in the future.

Table 10 summarizes the cumulative proportion of revenues generated by each of the major network carriers based on the nine density bins defined in Table 9. Overall, Tables 9 and 10 combine to paint a chilling prediction for the major network carriers. Even if LCCs were only to penetrate the entire 8th and 9th density bins (i.e., enter all the markets generating more than 500 passengers per day), the total proportion of network carrier revenue exposed to nonstop LCC competition would increase sharply relative to current (2002) levels: from 31.7% to 55.7%. Table 10 also indicates that the long term potential exposure varies significantly across carriers. For example, while the long term potential exposure of Alaska, American, Continental and United are all roughly 65%, the long term potential exposure of Delta, Northwest and US Airways is significantly less (42%-45%). Not surprisingly, these three carriers all operate at least one "small" hub (in particular, Cincinnati (Delta), Charlotte and Pittsburgh (US Airways) and Memphis (Northwest)). Since LCCs have traditionally focussed their entry on the most dense markets, the relatively higher proportion of "thin" routes these smaller hubs serve may actually provide these carriers with a degree of insulation versus LCCs. It is important to stress, however, that even among these carriers, LCC exposure is likely to increase dramatically in the years to come and thus have serious competitive consequences.

Table 10: Long Term Potential Nonstop Exposure, By Density Bin

	Density Bin									*2002*	*Bin 8 -*
	1	2	3	4	5	6	7	8	9	*Exposure*	*2002 Exposure*
Alaska	100.0	94.9	86.4	83.1	78.1	76.2	68.7	66.1	55.7	*27.1*	*39.0*
American	100.0	97.6	92.3	88.7	86.1	84.1	75.5	65.3	54.2	*33.2*	*32.1*
Continental	100.0	97.8	93.6	90.3	88.0	86.1	77.9	66.7	48.9	*37.4*	*29.3*
Delta	100.0	96.4	86.1	78.6	73.7	70.0	57.2	45.3	31.3	*28.1*	*17.2*
Northwest	100.0	92.9	81.6	74.6	69.8	65.9	52.3	42.4	29.2	*15.8*	*26.6*
United	100.0	96.6	91.7	87.7	84.9	82.7	74.8	67.7	58.5	*50.9*	*16.8*
US Airways	100.0	95.5	87.9	82.1	77.9	74.1	60.1	44.2	30.2	*19.8*	*24.4*
Total	100.0	96.2	88.8	83.7	80.0	77.1	66.4	55.7	43.0	*31.7*	*24.0*

Source: U.S. DOT DB1A Database.
Notes: 2002 exposure based on first and second quarter revenues. Figures represent the proportion of 2000 revenue generated in markets with given density bin or greater. Total figures represent the sum of the seven carriers.

5 Conclusions

This paper documents the growth of low cost carriers (LLCs) in the U.S. airline industry since 1990. In 2002, LCCs collectively carried nearly one in four domestic O&D passengers, a dramatically higher proportion than just twelve years earlier (7%). Moreover, we document the increasing overlap between the networks of the legacy hub-and-spoke carriers and those of the LCCs. The growing overlap of their respective networks has resulted in strong competitive pressures on the fares–and in turn–the revenues of incumbent carriers. In short, the rapid growth of LCCs has quickly become the primary force reshaping the competitive landscape of the U.S. airline industry. It is important to note that the recent growth of LCCs is not limited to the U.S. Indeed, LCCs also represent the fastest growing segment of the airline industry in Canada and throughout Europe.

Using a combination of probit and market decomposition analysis, we found that LCCs have primarily targeted markets with high traffic densities that allow them to leverage their comparative cost advantage. Since many incumbent network carriers also generate a substantial portion of their revenue from these same dense markets, they face–or will likely face–even greater revenue exposure from the LCCs as they continue to grow and enter new (and increasingly longer haul) markets. We estimate that in the long term, and additional 24% of the incumbent network carriers' revenues will potentially be exposed to further nonstop LCC competition, increasing their total exposure from 31.7% today to 55.7%.

LCCs are no longer niche segment of the airline industry whose influences are limited solely to particular geographic regions or leisure travellers. Indeed, over the last decade, LCCs have emerged as a national phenomenon that are fundamentally altering the market structure and competitive landscape of the U.S. airline industry. As LCCs continue to grow, many markets with high traffic density have become more "contestable" than they have ever been. Indeed, the relative ease of entry and the perceived “contestability” (Baumol, Panzar, and Willig 1982) of airline markets was one of the theoretical backbones of airline deregulation. In the current state of the industry, entries are swift, prevalent and often successful, partially confirming what the original planners of airline industry deregulation envisioned of the post-deregulatory era (Bailey and Panzar 1981, Bailey and Baumol 1984). However, in light of recent bankruptcy filings by both United Airlines and US Airways, the long-term sustainability of some of the large hub-and-spoke carriers is now in question. Consequently, the evolving direction of LCC versus full-service network competition will likely be the primary issue facing policy makers, business leaders, as well as academic researchers in the coming decade.

A Appendix

TABLE A1: LOW COST CARRIER OVERLAP WITH MAJOR NETWORK CARRIERS, 1990-2002

Proportion of Domestic Revenues Generated in Markets with LCC Competition													
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Alaska	2.7	2.3	6.1	47.0	44.0	53.9	64.8	65.0	58.9	59.8	53.0	52.3	51.7
American	10.7	10.8	11.1	16.1	17.7	24.2	25.0	25.6	31.9	42.7	46.3	52.3	55.9
Continental	11.3	10.4	12.1	20.3	26.9	32.4	35.0	34.2	35.8	41.0	45.6	60.8	61.1
Delta	4.3	4.7	4.5	11.6	21.4	28.9	31.4	30.4	32.6	37.5	38.7	45.1	47.1
Northwest	7.6	7.3	7.4	8.8	13.8	17.8	19.5	18.4	26.5	43.2	45.2	47.9	41.9
United	7.2	8.9	9.5	22.9	25.3	33.0	41.0	41.8	47.3	55.5	58.4	65.1	68.0
US Airways	5.8	3.9	3.4	4.5	7.8	16.6	16.9	15.8	18.2	21.6	29.3	36.7	34.6
Proportion of Domestic Passengers Travelling in Markets with LCC Competition													
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Alaska	6.8	8.3	8.9	56.2	54.1	65.8	76.9	75.8	69.3	69.0	64.5	64.6	64.2
American	18.4	18.4	17.2	21.4	23.6	31.6	33.6	33.3	39.0	50.8	55.4	58.6	61.4
Continental	15.6	12.8	14.0	23.7	30.5	38.9	42.7	39.2	40.4	47.1	54.0	66.4	67.0
Delta	7.8	8.5	7.3	16.1	29.0	36.1	41.7	38.5	41.1	46.4	47.4	55.1	56.5
Northwest	10.4	9.6	9.4	10.5	17.4	23.7	26.2	25.3	34.8	48.5	49.4	53.4	47.5
United	13.6	19.4	17.0	31.8	35.4	46.8	56.4	55.8	57.9	64.0	66.0	69.5	70.8
US Airways	10.8	7.8	5.9	7.0	10.4	21.4	23.5	21.3	24.3	28.6	38.8	47.2	44.1

Source: U.S. DOT DB1A Database, 1990-2002. Data for 2002 is from the first and second quarters.
Notes: LCC competition defined as a single LCC with at least a 5% share of O&D passengers.
LCCs include Air South, Access Air, AirTran, American Trans Air, Eastwind, Frontier, JetBlue, Kiwi, Morris Air, National, Pro Air, Reno, Southwest, Spirit, Sun Country, ValuJet, Vanguard and Western Pacific.

Table A2: Low Cost Carrier Share of O&D Passengers at Hubs, 1990-2002

Hub City	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Alaska													
Seattle			1.2	10.2	12.2	14.2	15.9	14.8	13.6	14.6	14.6	15.4	15.4
American													
Chicago	5.9	5.4	9.3	14.7	17.7	20.5	21.1	20.8	22.6	24.6	26.5	29.6	31.1
Dallas	24.5	24.3	24.2	26.0	28.2	28.4	27.5	25.7	24.3	25.6	26.3	27.9	25.1
Miami		0.2	0.2	1.4	3.8	8.9	9.9	10.8	12.8	15.6	19.1	22.5	27.0
St. Louis	12.2	14.4	18.1	21.4	22.1	24.4	23.9	23.7	23.4	22.9	25.0	25.6	21.6
Continental													
Cleveland			9.1	12.7	11.5	12.2	13.5	13.2	13.9	14.8	15.8	16.8	16.4
Houston	35.8	37.0	37.2	38.9	37.4	36.0	37.7	35.2	33.9	34.1	33.7	34.0	32.3
New York			0.2	1.2	1.8	1.9	2.6	2.0	3.6	4.6	8.0	13.1	16.5
Delta													
Atlanta			0.3	1.3	10.7	20.8	12.0	9.7	11.3	12.9	15.4	15.2	14.1
Cincinnati						0.7	1.1	1.0	0.1	2.0	0.4	-	-
Salt Lake City				29.7	29.5	32.9	26.4	21.0	20.6	22.1	23.1	24.4	21.6
Northwest													
Detroit	9.4	8.5	9.5	12.1	12.3	12.8	11.5	11.1	14.8	16.3	16.8	17.2	17.9
Memphis				0.2	5.0	6.7	3.2	3.3	4.6	5.4	5.8	6.2	6.7
Minneapolis				0.1		0.9	2.6	4.0	4.7	7.9	13.5	12.5	8.6
United													
Denver				1.6	2.9	5.9	9.8	10.3	9.0	12.0	15.5	16.0	18.5
Chicago	5.9	5.4	9.3	14.7	17.7	20.5	21.1	20.8	22.6	24.6	26.5	29.6	31.1
San Francisco	8.0	12.7	16.2	26.4	34.7	34.4	34.9	33.9	32.7	32.3	30.2	33.0	35.9
Washington, DC				0.7	4.5	9.0	9.3	10.9	12.7	13.6	16.5	20.6	23.5
US Airways													
Charlotte							1.3	0.7					-
Philadelphia				0.1	1.8	3.3	2.6	1.1	2.4	3.7	6.5	7.1	8.2
Pittsburgh							1.8	0.5	2.9	2.6	3.2	7.3	6.3

Notes: Airports in the following cities are grouped: Chicago (ORD, MDW), Dallas (DFW, DAL), Miami (MIA, FLL), Houston (HOU, IAH), Detroit (DTW, DET), San Francisco (SFO, OAK and SJC), Washington D.C. (IAD, DCA, BWI).
LCCs include Air South, Access Air, AirTran, American Trans Air, Eastwind, Frontier, JetBlue, Kiwi, Morris Air, National, Pro Air, Reno, Southwest, Spirit, Sun Country, ValuJet, Vanguard and Western Pacific.
Source: U.S. DOT DB1A Database, 1990-2002. Data for 2002 is from the first and second quarters.

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