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Entry strategy of Southwest Airlines*

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*Journal of Economic Literature (JEL) classification: C01 Econometrics, C13 Estimation, C25 Discrete regression and qualitative choice models; discrete regressors, C51 Model construction and estimation, C80 Data collection and data estimation methodology; computer programs - general, L10 Market structure; firm strategy, and market performance, L93 Air transportation (see http://www.aeaweb.org/journal/jel_class_system.html for classification system).

Keywords: airline strategy; discrete choice models, entry models, Southwest Airlines.

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Executive Summary

This report presents the results of a third year project “Projet de Synthèse” of the “IENAC06T” course, and was completed between Oct 2008 and Jan 2009.

The aim of this project is to understand the main determinants of Southwest Airline’s presence on U.S. domestic routes, over the period 2002 to 2007. A new dataset has been constructed, using quarterly and annual data from the U.S. Department of Transportation (DB1B and T100 Origin and Destination databases), and a number of socio-economic and geographic (regional) variables. A range of discrete choice (probit and logit) models have been built and estimated, both for individual quarters, and for the full sample period, and under various assumptions on the construction of key variables. The resulting model is seen to outperform one of Boguslaski et al.’s (2004, Review of Industrial Organization) recently published Southwest Airlines entry models, in terms of model fit.

The model is used both to examine Southwest’s current route presence, and to form predictions of its likely future behaviour. In particular, it is suggested that Southwest’s announced Mar 2009 entry into Minneapolis-Saint Paul International Airport (MSP) is likely to be more successful than its planned expansion into New York’s LaGuardia Airport (LGA). Further, the model is able to identify likely expansion of routes out of airports that are currently served by Southwest, such as Denver International Airport (DEN) and Bob Hope Airport (BUR), and can be used to explore the potential implications of a repeal of the 1979 Wright Amendment restricting Southwest’s traffic out of Dallas Love Field (DAL).
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1 Southwest Airlines

1.1 Company development

Southwest Airlines (IATA code WN), is an American airline with its headquarters in Dallas, Texas. It was founded in 1967 as the U.S. domestic aviation market started to deregulate. Following the overruling of several objections by American Airlines (AA), Delta Air Lines (DL), Eastern Airlines (EA) and United Airlines (UA), that were primarily made for strategic reasons, Southwest established its first flights in 1971, offering connections between Dallas Love Field (DAL), Houston, and San Antonio International Airport (SAT).[1]

Southwest is often recognized as the first company to have been successful in introducing a low-cost airline business model. Even though no generally accepted definition of a low-cost-carrier exists, there are some key features which identify a low-cost business model, and which are often referred to as the Southwest Airlines Paradigm: homogenous fleet (see Table 1), traditionally a dense point-to-point-network (mostly out of less congested secondary airports), internet-based electronic ticketing, and largely reduced on-board-service [14]. Southwest has operated profitably since 1973, and has attracted many other companies around the world to imitate elements of their strategy to some extent.[2]

1 The first of the Houston airports to be served by Southwest was George Bush Intercontinental Airport (IAH) in 1971, but all operations were moved to William P. Hobby Airport (HOU) in 1972.[2]

2 Southwest’s concentration on short-haul and medium-haul routes allows it to operate aircraft with similar performance characteristics (see Figure 2). Southwest’s major competitors, such as United and Delta, tend to have more diverse networks, with routes reaching from regional to intercontinental long-haul connections, and more heterogeneous fleets (see Table 3). Secondary airports can essentially be characterized as smaller airports (in terms of passenger numbers), that are close to important hub airports. They are often less congested than the hubs, which allows for lower operating costs and greater availability of slots. One such example can be found in Chicago, where Chicago Midway International Airport (MDW), which is used by Southwest, is a secondary airport to O’Hare International Airport (ORD). ORD is an important hub for the major carriers American and United, and an important international gateway.
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Table 1: Southwest fleet composition at June 2008. Range is measured in kilometers for an aircraft with maximum takeoff weight (MTOW) and the highest possible payload and PAX is the number of passengers.

Recently, a shift can be observed in Southwest’s business model. Mainly due to a less successful fuel-hedging strategy, Southwest posted a loss of $120 million for the third quarter of 2008, its first quarterly loss for 17 years.\(^3\) The airline is actively looking for new sources of revenue, and these include an increase in its share of business travellers, which fell from 40% to 25% over the last decade. The Business Select fare category, which provides advantages such as priority check-in and a free on-board drink, is expected to contribute to an annual revenue surplus of about $100 million. Southwest also plans to extend its market presence through codeshare agreements with the Mexican low-cost carrier Volaris and the Canadian low-cost carrier WestJet. These are due to come into effect in 2009 and 2010 respectively, enabling Southwest to offer international flights.[20] [21].

Southwest is currently the world’s largest airline, with more than 100 million passengers carried in 2007.[1] It operates 3400 daily flights, to 64 cities and 32 states across the U.S., with a fleet of more than 500 Boeing 737 (of the -300, -500 and -700-series as shown in Table 1 [2]). Table 2 illustrates the ranking of Southwest in comparison to its main domestic competitors. It can be seen that in

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\(^3\)Fuel hedging is one means by which an airline can stabilize its fuel costs. A given amount of fuel is purchased for a specified date in the future, based on a pre-determined ‘forward’ price. The airline benefits if the forward price is lower than the market price at the time of delivery. Regarding the 2008:3 quarter, Southwest negotiated prices for these fuel deliveries that were generally higher than the market price.[29] [30].
addition to the ‘major’ carriers, several other U.S. low-cost carriers like AirTran (FL) and JetBlue (B6) account for a reasonably large number of passengers in the U.S. domestic market. Hence, Southwest cannot only be considered to compete with the majors, but also with other low-cost carriers (LCCs). For instance, SkyWest operates regional networks across the entire U.S. It employs its fleet for UA as United Express, for DL as Delta Connection and for Midwest Connect. Hence, SkyWest competes with Southwest through its link with these three carriers.

1.2 Network development

The area within the circles in Figure 1 around representative airports served by Southwest, on the U.S. west coast (San Diego International Airport, SAN),

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4The official definition of a U.S. ‘major’ carrier is given by the U.S. Department of Transportation (DOT) as an airline with an annual operations revenue exceeding one billion US dollars. Following this definition, the U.S. major passenger carriers, in addition to AA, CO, DL, NW, UA and US, are AirTran Airways (FL), Alaska Airlines (AS), Frontier Airlines (F9), JetBlue Airways (B6) and Southwest itself. It is also common to deviate from this official definition, and to use ‘major’ in order to identify only AA, CO, DL, NW, UA and US.
the central U.S. (Dallas Love Field, DAL) and the U.S. east coast (Baltimore / Washington International Thurgood Marshall Airport, BWI) illustrates the destinations which can be reached nonstop with Southwest’s longest range aircraft, the Boeing 737-700 (which has a maximum range of 2150 nautical miles).

![Image of range chart](image)

Figure 1: Representative range chart [10] [11].

Flights to Hawaii, even though they would be within the range circle around San Diego, are not offered by Southwest. Flights with a two-engine aircraft such as the Boeing 737, across a region with no nearby alternate airport (like an ocean), require special performance by both aircraft and crew, which are not
satisfied by Southwest.

Southwest already offered its passengers access to Hawaii through a codeshare agreement with the Indianapolis based carrier ATA Airlines between 2005 and 2008. The agreement with ATA also allowed Southwest to have (codeshared) access to New York’s LaGuardia (LGA) and Ronald Reagan Washington National Airport (DCA). These airports are, with John F. Kennedy International Airport (JFK) and ORD, the only airports in the U.S. which are slot restricted, which complicates new services to and from these airports. Usually, the slots are assigned by the Federal Aviation Administration during an auction process. These Southwest services ended with ATA’s bankruptcy in April 2008.

Table 3 gives the airports at which Southwest has operations. While the airline claims to be a point-to-point-carrier, some centers of operations can clearly be identified. These, in terms of weekly departures, are the focus cities Las Vegas McCarran International Airport (LAS), Chicago Midway International Airport (MDW), Phoenix Sky Harbor International Airport (PHX), Baltimore (BWI), Oakland International Airport (OAK), Houston (HOU), Dallas (DAL), Los Angeles International Airport (LAX), Orlando International Airport (MCO), San Diego (SAN), Nashville International Airport (BNA) and, lastly, Denver International Airport (DEN).

\[5\] These performance requirements are placed under the umbrella of ETOPS (Extended-range Twin-engine Operation Performance Standards). Under normal conditions, a two-engine aircraft and its engines are designed to be able to fly 60 minutes with only one engine running to reach an airport for an emergency landing. An ETOPS-Certificate can extend this security margin, allowing an airline to widen its range of operation. To operate under ETOPS-conditions, an airline has to obtain an Operational Certificate from the responsible aviation authority. It has to account for special maintenance of the respective aircraft and special training for the crew, both on board and on the ground. For example, a two-engine aircraft operating between mainland U.S. and Hawaii needs an ETOPS-certificate for a one-engine-flight of 180 minutes.
Figure 2: Cities served by Southwest at July 2008. Service to Minneapolis - St. Paul will begin in March 2009.

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<td>3</td>
<td>5</td>
<td>1977</td>
<td>SW</td>
</tr>
<tr>
<td>Washington Dulles</td>
<td>IAD</td>
<td>VA</td>
<td>12</td>
<td>2</td>
<td>4</td>
<td>2006</td>
<td>NE</td>
</tr>
<tr>
<td>West Palm Beach</td>
<td>PBI</td>
<td>FL</td>
<td>12</td>
<td>2</td>
<td>4</td>
<td>2001</td>
<td>SE</td>
</tr>
<tr>
<td>Harlingen</td>
<td>HRL</td>
<td>TX</td>
<td>12</td>
<td>2</td>
<td>3</td>
<td>1975</td>
<td>SW</td>
</tr>
<tr>
<td>Norfolk</td>
<td>ORF</td>
<td>VA</td>
<td>11</td>
<td>2</td>
<td>6</td>
<td>2001</td>
<td>NE</td>
</tr>
<tr>
<td>Amarillo</td>
<td>AMA</td>
<td>TX</td>
<td>11</td>
<td>2</td>
<td>3</td>
<td>1978</td>
<td>SW</td>
</tr>
<tr>
<td>Fort Myers</td>
<td>RSW</td>
<td>FL</td>
<td>10</td>
<td>2</td>
<td>5</td>
<td>2005</td>
<td>SE</td>
</tr>
<tr>
<td>Jackson</td>
<td>JAN</td>
<td>MS</td>
<td>9</td>
<td>1</td>
<td>4</td>
<td>1997</td>
<td>SE</td>
</tr>
<tr>
<td>Corpus Christi</td>
<td>CRP</td>
<td>TX</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1977</td>
<td>SW</td>
</tr>
</tbody>
</table>

Southwest’s airports at September 2008. ‘Dep.’ refers to the number of weekly departures, ‘Con.’ is the number of nonstop connections from each airport, ‘Gates’ is the number of gates used by Southwest, and ‘Reg.’ is the airport’s geographic region [2].

Table 3: Southwest’s airports at September 2008.
Figure 3 shows the current allocation of the airports served by Southwest according to their geographic location. The southwest region (SW) is the core area of Southwest’s operations with 28 airports being served. The southeast (SE), northeast (NE) and midwest (MW) account for a total of 11 airports respectively, while only 4 airports are served by Southwest in the U.S. northwest (NW). Figure 4 shows how Southwest has expanded in the different regions to reach its current total of 65 destinations, the geographic situation of which is displayed in Figure 3. During the first ten years of operations (until 1980), Southwest’s network was concentrated in the southwest region of the U.S. From the late 1970s through to 1987, airports in Texas’ neighbouring southeast states were also added (Louis Armstrong New Orleans International Airport (MSY), Birmingham-Shuttlesworth International Airport (BHM) and also to Little Rock National Airport (LIT)).

Between 1980 and 1995, Southwest expanded into the midwest. Also significant is the extension of its network to the northwest: all of these destinations (Seattle-Tacoma International Airport (SEA), Portland International Airport (PDX), Boise Airport (BOI) and Spokane International Airport (GEG)) were added in 1994. This was essentially due to the merger with Morris Air in 1993. Morris Air was a Salt-Lake-City-based low-fare carrier, and its acquisition added a total of 14 new cities to the Southwest network, and the first of its airports in the northwest. Operations to the northeast began in 1993, with flights

---

6The U.S. states are allocated to regions as follows: southwest (SW): CA, NV, AZ, NM, UT, CO, TX, OK, AK, HI; southeast (SE): AR, LA, MS, AL, GA, SC, FL, NC, Puerto Rico, U.S. Virgin Islands, midwest (MW): ND, SD, NE, KS, MO, IA, MN, WI, MI, IN, IL, OH, KY, TN, northwest (NW): OR, WA, ID, MT, WY, and northeast (NE): VA, WV, PA, DE, MD, NJ, NY, CT, VT, RI, MA, NH, ME. For a complete list of U.S. airports and their corresponding regions, see Appendix D.

7In both Figures 3 and 4 Minneapolis-Saint Paul International Airport (MSP) has already been counted as a Southwest destination, although it will only come into service in March 2009.
Figure 3: Network diagram. The different colored areas illustrate the five identified regions of the U.S.: the southwest (SW), northwest (NW), midwest (MW), southeast (SE) and northeast (NE). An allocation of airports to these regions is given in Table 3. The numbers denote the total number of Southwest’s airports in the respective area [2].

to Baltimore (BWI), and saw a steady extension, most notably between 1996 and 2000. A second sudden expansion, like that which occurred in the northwest in 1994, took place in the southeast in 1996, with the inauguration of Florida services to Orlando (MCO), Tampa International Airport (TPA) and also to Fort Lauderdale-Hollywood International Airport (FLL). This was followed in 1997, 2001 and 2005, by Jacksonville International Airport (JAX), Palm Beach International Airport (PBI) and Southwest Florida International Airport (RSW).
Figure 4: Network development. The columns refer to the given time periods in steps of five years, except for the last period which goes as far as 2009. As in Figure 3, the different colours illustrate the five regions of the U.S. that have been identified [2].

Table 4 gives the number of domestic passengers carried at Southwest’s ten most important airports (defined in terms of the number of connections offered, and weekly departures), with Southwest’s ranking in terms of market share. In eight out of of ten of its most important airports, Southwest has the biggest share in terms of passenger numbers. Regarding the airports served by Southwest (see the Appendix A), there is no clear evidence that Southwest serves only secondary airports. Also (with regards to Table 4), only five of these airports, Midway (MDW), Baltimore (BWI), Oakland (OAK), Dallas Love Field (DAL) and Houston (HOU), can be identified as airports that are close to
<table>
<thead>
<tr>
<th>Airport</th>
<th>Total PAX ('000s)</th>
<th>WN PAX ('000s)</th>
<th>WN share (%) (rank)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Las Vegas (LAS)</td>
<td>40,000</td>
<td>15,881</td>
<td>39.40 (1)</td>
</tr>
<tr>
<td>Chicago (MDW)</td>
<td>16,909</td>
<td>14,055</td>
<td>83.12 (1)</td>
</tr>
<tr>
<td>Phoenix (PHX)</td>
<td>38,000</td>
<td>11,955</td>
<td>31.17 (2)</td>
</tr>
<tr>
<td>Baltimore (BWI)</td>
<td>20,478</td>
<td>11,133</td>
<td>54.37 (1)</td>
</tr>
<tr>
<td>Oakland (OAK)</td>
<td>12,584</td>
<td>8,374</td>
<td>66.55 (1)</td>
</tr>
<tr>
<td>Houston (HOU)</td>
<td>8,721</td>
<td>7,805</td>
<td>89.49 (1)</td>
</tr>
<tr>
<td>Dallas (DAL)</td>
<td>8,159</td>
<td>7,717</td>
<td>94.58 (1)</td>
</tr>
<tr>
<td>Los Angeles (LAX)</td>
<td>42,000</td>
<td>6,926</td>
<td>16.67 (3)</td>
</tr>
<tr>
<td>Orlando (MCO)</td>
<td>34,000</td>
<td>7,803</td>
<td>23.38 (1)</td>
</tr>
<tr>
<td>San Diego (SAN)</td>
<td>17,997</td>
<td>6,601</td>
<td>36.68 (1)</td>
</tr>
</tbody>
</table>

Table 4: Southwest market share July 2007 - August 2008. [3]

bigger hubs. While Oakland (OAK) is Southwest’s most important airport in the San Francisco area, San Francisco International Airport (SFO) and Norman Y. Mineta San Jos International Airport (SJC) are also served. In the Washington-Baltimore-Area, Southwest offers flights from Baltimore (BWI) and Washington Dulles International Airport (IAD). Las Vegas McCarran International Airport (LAS) and Phoenix Sky Harbor International Airport (PHX) are the only airports in their respective areas where no other airports are offered (Phoenix (PHX) is also a hub of US Airways). Regarding Orlando (MCO) and San Diego (SAN), smaller airports can be found, in close proximity, which are not served by Southwest. Los Angeles (LAX), for instance, is a focus city for United, American and Delta. Moreover, the Los Angeles area offers many other, less congested airports, such as Burbank (BUR), Los Angeles Ontario (ONT) and John Wayne Airport (SNA), which are also served by Southwest.
2 Core data

The main dataset used as the starting point for this project was provided by the U.S. Department of Transportation (DOT). The raw data comprises details on the individual tickets (itineraries) for 10% of all flights on U.S. domestic routes, by quarter, over the 6-year period 2002:1 to 2007:4. The raw data was parsed by Roseline Bilina and Steve Lawford, to give (a) operating carrier, taken from the six ‘major’ carriers listed in the Introduction (American, Continental, Delta, Northwest, United and US), and Southwest, (b) nondirectional nonstop or one-stop route, defined by the endpoint airports, and (c) total number of passengers carried by each carrier on the route. From a separate datafile containing the geographical coordinates (latitude and longitude) of the endpoints, (d) the length of each route (km) was calculated. The database used in the econometric modelling of route presence below consists of 27,966 airport-pairs (one-stop as well as nonstop routes), between a total of 237 airports (a list of the airports is given in Appendix D).

3 Modelling market and route presence

3.1 Motivation and collection of additional data

The analysis of Southwest’s presence on any given route will depend upon multiple factors, and this project reports the attempt to build an explicit econometric model in order to capture some of the more important effects. As a first step, it is necessary to consider route-specific variables that could determine the intrinsic nature of a given route, such as route demand, the composition of the customer base, and geographical characteristics of the route. Secondly, the degree of
competition faced by Southwest on each given route must be assessed, and this will include hub analysis, and the presence of particular types of competitor (low-cost or major, for instance). The econometric modelling step will use these variables to ‘explain’ the likelihood that Southwest will be present on a route that has particular characteristics. Below, and in the following sections, the additional variables that will be used in this project are presented.

In particular, data (in addition to the Core Data detailed above) was collected or constructed on (e) Gross Domestic Product by region (annual data for 2007), (f) population by region (annual data for 2007), (g) U.S. airport by region (time-invariant), (h) U.S. airports that are affected by the 1979 Wright Amendment restricting Southwest’s traffic out of Dallas Love Field (DAL) (generally time-invariant across our sample period, although a minor change led to Southwest serving Dallas DAL to Kansas City International Airport (MCI) and Lambert - St. Louis International Airport (STL) from 2005 onwards), (i) U.S. airports that are slot-restricted (annual data for 2006), (j) the number of years for which Southwest has served each given airport, (k) the average delays at each U.S. airport (annual data covering the period 2002 to 2007, collected from the DOT), and (l) the number of scheduled departures of JetBlue Airways, AirTran Airways, Frontier Airlines and Alaska Airlines, by airport (quarterly data for 2002 to 2007, collected from the T100 database).

From this data, proxies are built for e.g. potential route demand (based on population), for airports in terms of use as hubs by given carriers, and for use as secondary airports, using location data to examine nearby airports and/or routes. Conditioning on sectors is used to examine regional behaviour, while average airport delays are used to explore Southwest’s ‘reaction’ to congestion.
3.2 Socio-economic variables

The decision of an airline to serve a given airport (or route) are likely to be influenced by local socio-economic characteristics. Variables based upon regional Gross Domestic Product (GDP) and regional population (Pop.) are introduced into the models, in order to capture the attractiveness of an airport (or route) in terms of major sources of regional revenue (for instance, tourism or business activities, which may be used to determine whether a route can be classified as primarily leisure or business), and the size of the potential customer base.

Data on GDP was obtained from the U.S. Bureau of Economic Analysis (BEA) [42]. The U.S. is divided by region, into Metropolitan and micropolitan Statistical Areas (MSAs and mSAs), and GDP data is available for the MSAs. Total GDP is used, as are the parts that are made up by the leisure-sector and the business-sector, which is available for most of the MSAs. An exact definition of the fields of activity within the leisure and business subcategories (by the BEA) is given in Appendix C.

Population data was taken from the U.S. Census Bureau, and is available for both MSAs and mSAs [37]. This division allows for population and GDP figures to be assigned to distinct regional areas, and consequently to the airports that are found within those regions (see Figure 33).

Based on these regionally determined (and hence airport-specific) datasets on GDP and population, the following variables are constructed:

\footnote{The U.S. Bureau of Economic Analysis (BEA) gives the following definition of the professional and leisure sectors: \textit{business-sector}: The “Professional and Business Supersector” is part of the “Service-providing Industries” and consists of the following sectors: “Professional, Scientific and Technical Services”, “Management of Companies and Enterprises” and “Administrative and Support and Waste Management and Remediation Services”; and the \textit{leisure-sector}: The “Leisure and Hospitality Supersector” sector consists of the following sectors: “Arts, entertainment and recreation”, “Accommodation and Food Services”. An exact definition, given by the North American Industry Classification System, containing the activities that are included within these sectors, can be found in Appendix C.}
The geometric mean of the population at the departure and arrival airports gives the ‘population’ variable for each route (and is intended to approximate the potential customer demand for the route, since the demand itself is very difficult to define and measure exactly); the square of the population variable is also used, for reasons that will be discussed below:

\[ \text{Pop. and } \text{Pop.}^2 \]

The region-specific ratio of that component of GDP that is contributed by the leisure-sector or the business-sector, to the total GDP, is computed for each airport. This creates two dummy (binary) variables for each airport, which take value 1 when the business ratio is greater than 10 percent, or when the leisure ratio is greater than 5 percent, and value 0 otherwise:

\[
\frac{\text{GDP}_\text{Leisure}}{\text{GDP}_\text{Total}} > 5\% : \text{Leisure} = 1, \\
\text{and} \\
\frac{\text{GDP}_\text{Business}}{\text{GDP}_\text{Total}} > 10\% : \text{Business} = 1.
\]

Presumably, population will have a positive effect on Southwest’s likelihood of serving a route, since a larger population should represent a bigger (potential) local market. The influence of the GDP indicators, that determine whether a route is predominantly professional or leisure, cannot easily be determined in advance of the modelling process. Southwest serves not only typical business destinations such as Midway (MDW) or Philadelphia International Airport (PHL), but also leisure destinations such as Fort Lauderdale (FLL) and Southwest Florida International Airport (RSW) (see Southwest’s route map in Figure 2).
3.3 Geographic (spatial) variables

3.3.1 Regional division

The models also take the geographic location of the airports into account. The surface of the U.S. is divided into five categories, with values ranging from 1 to 5: southwest (1), southeast (2), midwest (3), northwest (4) and northeast (5) (see Table 2 for a classification of Southwest’s airports by region). The use of this variable allows for a more precise description of the traffic flows between the respective regions. The 5 region values are used to create another 15 dummy (binary) variables for the model, corresponding to the 15 possible combinations of the regions, and including intra-regional traffic (see Table 5). For example, Reg.1 denotes routes within the southwest region, such as Houston (HOU) - Dallas Love Field (DAL), while Reg.14 stands for routes between the northwest and the northeast, such as Seattle (SEA) - Philadelphia (PHL).

<table>
<thead>
<tr>
<th>Pairs SW</th>
<th>Pairs SE</th>
<th>Pairs MW</th>
<th>Pairs NW</th>
<th>Pairs NE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW-SW</td>
<td>SE-SE</td>
<td>MW-MW</td>
<td>NW-NW</td>
<td>NE-NE</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>10</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>SW-SE</td>
<td>SE-MW</td>
<td>MW-NW</td>
<td>NW-NE</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>11</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>SW-MW</td>
<td>SE-NW</td>
<td>MW-NE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW-NW</td>
<td>SE-NE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW-NE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Regional division variable. The 5 geographic regions give rise to 15 combinations for regional routes, including intra-zonal traffic, which are denoted by the variables Reg.1 to Reg.15.

In the models, Reg.1 to Reg.15 correspond to traffic ‘corridors’ between and within the five geographical regions. The idea is to see whether Southwest’s expansion strategy can be identified in terms of preferred regions. As shown in
Figures 3 and 4. Southwest’s network now covers all five geographic regions of the U.S., and so it is not immediately obvious which traffic corridor(s) will be most important, before the modelling step has been completed.

3.3.2 Distance

The distance between two airports is likely to have an important influence on the decision to serve a route. Southwest’s fleet permits operations across the entire U.S. (see Figure 1). However, the aim here is to examine whether there is any tendency for Southwest to operate routes within a certain range. For example, Southwest may only enter routes which are sufficiently long, so that they do not directly compete with car travel. Moreover, there is perhaps also a certain upper limit on route length, above which Southwest will not wish to enter a route. The following route-distance-related variables are introduced:

\[ Dist. \text{ and } Dist^2 \]

and

\[ Dist. \leq 200. \]

The quadratic term \( Dist^2 \) allows for measurement of a ‘saturation limit’ for route length. That is, it is expected that the influence of distance on the probability of route presence is positive, up to a certain level, after which an increase in distance may start to reduce the probability. The dummy variable, taking value 1 (0) when distance is no more than (above) 200km is expected to be negative due to the avoidance of competition with car travel that was mentioned above. However, this variable has an additional purpose, which is to ‘force’ the model to ‘recognize’ routes that are technically possible, such as San Francisco (SFO) - Oakland (OAK), but that do not have any practical meaning (in this
case, the airports are separated by only a few kilometers). The data on distance between airports is computed directly as the great circle distance based upon the (difference between the) latitude and longitudes at the airport endpoints.

3.4 Airport-specific variables

3.4.1 Political and legal / regulatory issues

So far, a number of geographic, technical and economic constraints on Southwest’s route choices have been considered: network expansion may follow a certain geographic structure; technical issues such as requirement of ETOPS-certification may preclude air transport service in certain regions (see Section 1.1); also, the nature of the local economy may affect a carrier’s decision to serve a route. However, political and legal constraints may also impose strong constraints on network development.

When considering the Dallas airports, the Wright Amendment must be taken into account. In 1974, a new international airport was built in the Dallas - Fort Worth region: DFW. To protect this investment, the Wright Amendment restricted the competition the new airport could face from Dallas Love Field (DAL). Flights from DAL were restricted to those states that directly neighbour Texas (namely, Louisiana, Arkansas, Oklahoma and New Mexico). Flights to other states were only allowed on planes with a maximum capacity of 56 seats. In 1997, the law was weakened to allow services to Alabama, Kansas and Mississippi, and Missouri followed in 2005. A further change was made in 2006, enabling one-stop flights to airports outside of the Wright-zone. Only Southwest and American currently operate out of DAL. The Wright Amendment will be repealed in 2014, from which time domestic nonstop flights will be possible throughout the U.S.
At the same time, DAL’s capacity will be reduced from 32 to 20 gates \[24\] \[25\]. Additionally, *slot restrictions* must be taken into account. High levels of congestion results in slots being auctioned at some airports, as mentioned in Section 1.1. The airports in our dataset that are affected by slot restrictions are Washington National (DCA), John F Kennedy (JFK), Chicago O’Hare (ORD) and LaGuardia (LGA).

Introducing these variables into the econometric models is not straightforward, due to a particular technical relationship between the Wright Amendment and slot restriction variables with the variable that captures Southwest’s presence on a route. This will be discussed further in Section 5. Even if these variables cannot be formally introduced into the models though, they can nevertheless be studied. For example, the model could predict a high likelihood of Southwest’s presence on a route such as Dallas Love Field (DAL) - San Francisco (SFO), or on routes out of LaGuardia (LGA). Since these routes cannot currently be served, either due to the Wright Amendment or because of slot restrictions, while the model does not have this information in the form of an explanatory variable, the results can then be interpreted in terms of the probable effect of a *removal* of the restriction(s).

### 3.4.2 Hubs and focus airports

Some key airports can be identified in the Southwest network, whether in terms of weekly departures or local market share (see Tables 3 and 4). To accommodate this, a Southwest ‘hub’ variable is constructed. For each airport and for each quarter in the core data set, the ratio of Southwest passengers to the total number of passengers at the airport is computed. A ranking of these ratios enables
construction of a variable measuring the degree of importance of each airport within the Southwest network. Four groups of ratios are retained, which result in four mutually exclusive Southwest hub dummy variables, each taking value 1 when the airport is a hub of that level:

\[
\frac{PAX_{\text{Southwest}}}{PAX_{\text{Total}}} < 30\% : \quad SW_{\text{Hub,1}} = 1,
\]

\[
30\% \leq \frac{PAX_{\text{Southwest}}}{PAX_{\text{Total}}} < 50\% : \quad SW_{\text{Hub,2}} = 1,
\]

\[
50\% \leq \frac{PAX_{\text{Southwest}}}{PAX_{\text{Total}}} < 70\% : \quad SW_{\text{Hub,3}} = 1,
\]

\[
\frac{PAX_{\text{Southwest}}}{PAX_{\text{Total}}} \geq 70\% : \quad SW_{\text{Hub,4}} = 1.
\]

For each airport pair in the sample, the two endpoint hub dummy variables are compared, and the higher value is chosen to determine the ‘hub nature’ of the route itself. For example, the route Houston (HOU) - San Francisco (SFO) would be a $SW_{\text{Hub,4}}$ route, due to the fact that HOU is a $SW_{\text{Hub,4}}$ airport and SFO is a $SW_{\text{Hub,1}}$ airport for Southwest. It could be expected that, even if Southwest is not a typical hub-and-spoke airline, the influence of the $SW_{\text{Hub,x}}$ variable would have a bigger influence on Southwest’s route presence as $x$ increases.

The same ranking of the significance of each airport is performed for each of the six majors: AA, CO, DL, NW, UA and US, which gives another 24 (6 carriers × 4 variables) hub dummy variables. For instance, for US, this is based
upon the ratio \( \frac{PAX_{US\ Airways}}{PAX_{Total}} \), and gives the hub variables \( US_{Hub}1 \) to \( 4 \).

In an econometric model with a constant term (as is usually the case), a ‘full set’ of mutually exclusive dummies cannot be included, since a linear combination of the variables will be perfectly correlated with the constant (the problem of perfect multicollinearity), which means that the estimation cannot be performed. For this reason, the variables corresponding to percentages below 30%, such as \( SW_{Hub1} \), cannot be included in the model, if the other hub variables i.e. \( SW_{Hub2}, SW_{Hub3} \) and \( SW_{Hub4} \) are included. Further, the variables for the six majors (but not for Southwest) are aggregated respectively: for example, the US hub variables \( US_{Hub2}, US_{Hub3} \) and \( US_{Hub4} \) are used to build \( US_{Hub} \), giving one variable which designates an airport to be a hub of US when the passenger percentage is above 30%. More explanation of the mathematical impact of the dummy variables is given in Section 5.

The influence of these variables on Southwest’s behaviour cannot easily be predicted. The model results will permit examination of whether Southwest avoids direct competition with a major carrier in one of its hub airports (or vice-versa), or not; and the impact on Southwest’s entry strategy of its own hubs and focus airports. For example, Southwest is not present in Delta’s Atlanta (ATL) hub, but entered US’s hub in Philadelphia (PHL) in 2004 (see Tables 3 and 33.)

3.4.3 Secondary airports

As described in Section 1.1, an important feature of many low-cost carriers has been operations out of secondary airports. These airports allow access to the markets of large metropolitan areas (such as Chicago for Midway (MDW)), without some of the negative impacts like congestion (affecting Chicago O’Hare
(ORD), for instance). Southwest currently serves both types of airports: it only serves the secondary airport Fort Lauderdale (FLL) in the Miami Area (and not American Airline’s Miami International (MIA) hub). In contrast, Southwest’s services in the San Francisco Bay Area go to San Francisco International (SFO) (a hub airport for UA; see Table 33), as well as to Oakland (OAK) and San Jose International (SJC), which are considered to be secondary airports for SFO.

An airport is determined to be secondary if it is in close proximity to a major’s hub airport (and not for Southwest), as defined in Section 3.4.2. For example, MDW is a secondary airport for ORD, and is located close to ORD, which is a hub airport for AA (and also for UA). Thus, the variable \( AA\_{Hub} \) will take the value 1 for each ORD city-pair. Midway (MDW) is not even served by AA (or by any other major), and so \( AA\_{Hub} \) will take the value 0. This is a simple example of a hub airport which has a secondary airport in a neighbourhood of less than 50km.

The proximity is defined in accordance with two distances, creating dummy variables for two cases, depending upon whether a hub airport is within a range circle of 50km or 100km around an airport (calculated using coordinates):

\[
\text{Distance to hub airport} < 50\text{km}: \quad \text{Hub}_{0,50} = 1,
\]

\[
\text{Distance to hub airport} \geq 50\text{km and} \leq 100\text{km}: \quad \text{Hub}_{50,100} = 1.
\]

Again, Southwest’s current route network does not permit clear conclusions to be drawn in advance of modelling. Southwest is a low-cost carrier, but its airport map (see Figure 2) shows that it does not operate only out of secondary airports.
3.4.4 Airport congestion

The choice of secondary airports is, among other things, strongly affected by the problem of airport congestion. One of the key aims of low-cost companies is to maintain short turn-around times for their airplanes, to maximize the utilization of their fleet. The effects of congestion on airports, such as delayed arrivals and departures, compromise efficient fleet usage. It is checked whether the maximum average departure or arrival delay (across the endpoints) of a route is important factor in determining Southwest’s route presence. Data on average airline on-time-performance was taken from the U.S. Bureau of Transport Statistics (BTS). The data reports the ratio of the number of departures and arrivals which were delayed by more than 15 minutes at a given airport, to the respective total of departures and arrivals at that airport, for each of the years 2002 to 2007. Two variables are derived:

\[
Max_{DEP\ Delay} = \frac{DEP_{Delay > 15}}{DEP_{Total}},
\]

\[
Max_{ARR\ Delay} = \frac{ARR_{Delay > 15}}{ARR_{Total}}.
\]

Presumably, these variables will have a strong negative effect on Southwest’s route presence. Nevertheless, a definite answer cannot yet be given. For example, Southwest is currently looking to enter New York’s LaGuardia (LGA) airport, which is heavily affected by congestion [36].
3.4.5 Low-cost and other competition

The model already contains two variables that aim to measure the competition that Southwest faces from the six major carriers: (1) the core data includes the number $n$ of carriers (i.e., the number of majors and Southwest) present on a route. To use this variable, Southwest has to be removed from the number of carriers $n$, creating the number of competitors. Then, the effect of the correlation between the number of competitors and population must be investigated (since the number of airlines serving a certain route might be strongly influenced by population, and so by the size of the markets of the two endpoint cities). These considerations are discussed further in Section 5, but for a first analysis, the number of competitors gives a measure of the degree of competition on each route; (2) the passenger-hub dummy variables defined in Section 3.4.2 measure the importance of an airport for each of the major carriers (or Southwest) in terms of passenger percentages, and give an additional measure of the level of competition that Southwest will face at each airport.

Two additional competition factors that affect Southwest are identified: (3) the influence of competition from low-cost carriers in the U.S. domestic market has to be taken into account: AirTran Airways (FL), Frontier Airlines (F9) and JetBlue Airways (B6) are considered (and are not assumed here to be major carriers) and as seen in Table 2, each of these three low-cost companies accounts for a reasonable number of passengers; (4) lastly, Alaska Airlines (AS) is incorporated in the construction of variables to measure competition.\footnote{Following Ito and Lee (2003), “Low cost carrier growth in the U.S. airline industry: past, present and future”, Alaska Airlines is not considered to be a low-cost carrier.} Alaska Airlines does not operate intercontinental services, which distinguishes it from the six majors, but neither does it follow a low-cost carrier business model.
which marks a difference between Alaska and the other low-cost carriers. Alaska is included in the models as a further competition factor for Southwest.

The influence of the four carriers Jetblue, Frontier, Airtran and Alaska is included through dummy variables, which take value 1 at each of the sample airports at which one of the respective carriers is present.\footnote{An overview of the routes served by these carriers is given in the figures of Appendix B.}

4 Discrete choice models

4.1 Model motivation

The model of Southwest’s route presence has to satisfy one major requirement: the outcome, while potentially being driven by discrete factors (such as the number of competitors on the route, or the airport category), and continuous factors (such as the population and GDP associated with the route’s endpoints), is a scalar binary variable, i.e. it will take the value $y = 1$ if Southwest is present on any given route, and $y = 0$ if Southwest is absent from the route. A probability model is designed that will capture the likelihood that Southwest will be present on any particular route, as a function of relevant explanatory variables:

$$\text{Prob(Southwest present on a route)} := \text{Prob}(y = 1) = F(\text{relevant parameters}),$$

(1)

where $F()$ is some function. It is assumed that $x$ is a $k \times 1$ vector of explanatory variables (e.g. number of competitors on a route, GDP, etc.), and $\beta$ is a $k \times 1$ vector of unknown weights, that are to be estimated. Then, (1) can be rewritten
as:

\[
\text{Prob}(y = 1) = F(x, \beta), \quad \text{Prob}(y = 0) = 1 - F(x, \beta),
\]

using the fact that \( y = 0 \) or \( y = 1 \).

### 4.2 A first attempt: the linear probability model

The simplest approach to specifying the right-hand-side of equation (2) is to use a linear function

\[
F(x, \beta) = x'\beta;
\]

where it can be seen that the linear probability model has an underlying linear regression, since the conditional expectation \( E(y|x) = F(x, \beta) \), whereupon

\[
y = E(y|x) + (y - E(y|x)) := x'\beta + u,
\]

where \( u \) is a residual error term. Several difficulties arise from the linear regression model when \( y = 0 \) or \( y = 1 \) are the only possible realizations of the variable of interest.

The first problem comes from the residuals. Due to the fact that \( y \) is a binary variable, the residuals can only take two values, as follows:

\[
u \in \{-x'\beta, 1 - x'\beta\},
\]

where \( u = 1 - x'\beta \) as \( y = 1 \), with probability \( \text{Prob}(y = 1) = x'\beta \), and \( u = -x'\beta \) as \( y = 0 \), with probability \( \text{Prob}(y = 0) = 1 - x'\beta \). The conditional expectation
of \( u \) is calculated in (6) as:

\[
E(u | x) = (-x' \beta) \text{Prob}(y = 0) + (1 - x' \beta) \text{Prob}(y = 1)
\]

\[
= (-x' \beta)(1 - x' \beta) + (1 - x' \beta)(x' \beta) = 0,
\]  \hspace{1cm} (6)

from which the conditional variance of \( u \) is:

\[
\text{Var}(u | x) := E(u^2) = (-x' \beta)^2 \text{Prob}(y = 0) + (1 - x' \beta)^2 \text{Prob}(y = 1)
\]

\[
= (-x' \beta)^2 (1 - x' \beta) + (1 - x' \beta)^2 (x' \beta) = (x' \beta)(1 - x' \beta).
\]  \hspace{1cm} (7)

Equation (7) clearly shows that the variance is not constant, but depends upon \( x \), which implies heteroscedasticity. The second problem is rather more serious: essentially, there is no guarantee that the estimated probabilities \( \hat{\text{Prob}}(y = 1) \) and \( \hat{\text{Prob}}(y = 0) \) will be between 0 and 1, and furthermore, the estimated variances from equation (7) will not necessarily be positive.

4.3 Particular models: the probit and the logit

Two probability models are now introduced which are more appropriate, since they impose the requirement that the predicted probabilities lie between 0 and 1. The function \( F() \) is chosen to be a statistical cumulative distribution function (cdf). These functions are well-understood, and map any real number to the
interval \([0, 1]\), and so:

\[
\lim_{x' \beta \to \infty} F(x' \beta) = \lim_{x' \beta \to \infty} \text{Prob}(y = 1) = 1,
\]

\[
\lim_{x' \beta \to -\infty} F(x' \beta) = \lim_{x' \beta \to -\infty} \text{Prob}(y = 1) = 0.
\]

In theory, any valid cdf could be used, but for practical reasons either the normal distribution or the logistic distribution is chosen. The normal distribution leads to the \textit{probit model}, where \(\phi\) is the probability density function (pdf) of the standard normal \(N(0, 1)\), and \(\Phi\) is the cdf:

\[
\text{Prob}(y = 1) = \int_{-\infty}^{x' \beta} \phi(t) dt = F(x' \beta) = \Phi(x' \beta).
\]

Due to its mathematical convenience, the logistic distribution \(\Lambda\) is also used, which leads to the \textit{logit model}:

\[
\text{Prob}(y = 1) = \frac{e^{x' \beta}}{1 + e^{x' \beta}} = F(x' \beta) = \Lambda(x' \beta).
\]

The shape of these two distributions (both the cdfs and the pdfs) are relatively similar, although the logistic distribution has heavier tails. The two models often give similar fits to the data [43]. Regardless of which distribution is used, it is important to note that, as well as the coefficients in the \(\beta\) vector, the marginal effects must also be taken into account. The general form of the derivative of the cdf \(F()\) gives the following for the pdf \(f()\):

\[
\frac{\partial \text{Prob}(y = 1)}{\partial x} := \frac{\partial F(x' \beta)}{\partial x} = \frac{\partial F(x' \beta)}{\partial x' \beta} \frac{\partial x' \beta}{\partial x} = f(x' \beta) \beta.
\]
For the probit and logit models, \[10\] gives the following:

\[
\frac{\partial \text{Prob}(y = 1)}{\partial x} = \Phi(x'\beta) \beta, \quad \frac{\partial \text{Prob}(y = 1)}{\partial x} = \Lambda(x'\beta)[1 - \Lambda(x'\beta)]\beta, \quad (11)
\]

which depends upon both \(\beta\) and \(x\) (unlike standard linear regression).

### 4.4 Further model interpretation (the logit)

The following numerical example illustrates a way to interpret the results from a logit model. The odds-ratio gives the ratio of the probabilities of events \(y = 1\) and \(y = 0\). For the logit model \(9\), this ratio may be expressed as follows:

\[
\frac{\text{Prob}(y = 1)}{\text{Prob}(y = 0)} = \frac{e^{x'\beta}}{1 + e^{x'\beta}} = e^{x'\beta}, \quad (12)
\]

where the derivative with respect to the \(j\)th explanatory variable is:

\[
\frac{\delta \left( \frac{\text{Prob}(y = 1)}{\text{Prob}(y = 0)} \right)}{\delta x_j} = e^{x'\beta} \beta_j. \quad (13)
\]

Now assume that \(x_j\) increases by one unit, and that the estimated value \(\hat{\beta}_j = 0.1\). Then, the result of a changed \(x_j\) can seen using \(13\). The multiplicative factor is \(e^{0.1} \approx 1.105\). Thus, an increase in the explanatory variable \(x_j\) by one unit raises the probability of the event \(y = 1\), relative to the \(y = 0\), by about 10.5%.

### 4.5 Model estimation

The unknown vector of weights \(\beta\) is estimated by maximum likelihood. This chooses \(\beta\) to maximize the probability of observing \(\{y_i\}_{i=1}^N\) (this variable indicates Southwest’s presence or absence from any given route, from a total of \(N\) routes),
given a set of data in \( \{x_i\}_{i=1}^N \) (these are the corresponding vectors of explanatory variables). The likelihood function is the product of the pdfs of the individual observations \( y_i \), which each follow a Bernoulli distribution:

\[
f(y_i) = p^{y_i}(1-p)^{1-y_i} \quad y_i \in \{0, 1\} \quad p \in [0, 1],
\]

where \( y = 1 \) with \( \text{Prob}(y = 1) = F(x'\beta) := p \) and \( y = 0 \) with \( \text{Prob}(y = 0) = 1 - F(x'\beta) = 1 - p \). The log-likelihood (taken for mathematical convenience) is then given by:

\[
\ln L(\beta) = \ln \prod_{i=1}^N f(y_i) = \sum_{i=1}^N \ln f(y_i) = \sum_{i=1}^N \{y_i \ln F(x'\beta) + (1-y_i) \ln[1 - F(x'\beta)]\},
\]

(15)

with \( f(y_i) \sim y_i, p_i \) and \( p_i \sim x_i'\beta \). The maximum likelihood estimator solves:

\[
\hat{\beta}_{\text{ML}} = \arg \max_\beta \ln L(\beta),
\]

which has first-order conditions

\[
\frac{\partial \ln L(\beta)}{\partial \beta} = \sum_{i=1}^N \frac{y_i - i}{F_i(x'\beta)} f_i(x'\beta)x_i + (1-y_i) \frac{1}{1 - F(x'\beta)} (-f(x'\beta)x_i)
\]

\[
= \sum_{i=1}^N \frac{f_i(y_i - F_i)}{F_i(1 - F_i)} x_i = 0.
\]

(16)

For the probit and logit models, (16) reduces to:

\[
\frac{\partial \ln L(\beta)}{\partial \beta} = \sum_{i=1}^N (y_i - \Lambda_i)x_i \text{ (logit),} \quad \frac{\partial \ln L(\beta)}{\partial \beta} = \sum_{i=1}^N \frac{\phi_i(y_i - \Phi_i)}{\Phi_i(1 - \Phi_i)} x_i \text{ (probit).}
\]

(17)

Further, the Hessian matrix \( H \) of second derivatives of (16) with respect to \( \beta \) has
to be negative definite (the second-order condition for the maximization). The estimated Hessian \( \hat{H} \) is used to build an estimated variance-covariance matrix \( \hat{AVar} \), whose elements are used for hypothesis testing:

\[
\hat{AVar}(\hat{\beta}_{\text{ML}}) = \hat{H}^{-1} B \hat{H}^{-1},
\]

with

\[
\hat{H} := \frac{\partial \ln(L)}{\partial \hat{\beta} \partial \hat{\beta}'} |_{\hat{\beta} = \hat{\beta}_{\text{ML}}}, \quad B =: \sum_{i=1}^{N} g_i^2 x_i x_i',
\]

where the \( g_i \)'s in (18) are the terms multiplying \( x_i \) in the foc of the probit and the logit models respectively, specified in (17).

4.6 Model inference

The \( t \) tests with null hypothesis \( H_0 : \beta_j = 0 \) are assessed for the significance of the estimated coefficients \( \hat{\beta} \) (these are used to check whether the \( j \)th explanatory variable \( x_j \) has an influence on the probability of Southwest being present on a route (\( y = 1 \)). To go one step further regarding the chosen model, the likelihood ratio test can also be performed, and examines whether the explanatory variables jointly drive the probability of Southwest being present on a route (in other words, whether the model is ‘useful’ at all). The null hypothesis is \( H_0 : \beta_1 = \beta_2 = \ldots = \beta_k = 0 \), and the test statistic follows a (large sample) chi-squared distribution. The ‘information value’ (or goodness-of-fit) of the models is examined by computing McFadden’s \( R^2 \). Similar to conventional \( R^2 \), this should be as far as possible away from zero. However, qualitative interpretation is not easy, and multiple models must be compared, in order to deliver a reliable interpretation of model quality.
5 Model development

In this section, the construction of the model is described step-by-step. The objective is to see how well each variable, or change in model specification, changes the quality of the regression results, and to explain the mathematical impacts of introducing each of the variables in the model (as introduced in Sections 3.1 to 3.4.5). The discussion of Models 1 to 10 below is based on the data from the final quarter of the sample, 2007:4. Once the best model has been specified, it is applied to the full sample period of 24 quarters (i.e. 2002:1 through to 2007:4). Furthermore, regression results following slight modifications of the best model are presented, as a check on the robustness of some of the assumptions that were made when constructing the variables themselves.

5.1 Model 1: Distance and population

The first model takes only two variables into account: the Distance $Dist.$, and the population $Pop.$ For each airport-pair, the geometric mean of the population is computed, giving one population value for each route. The scaling of the variables is intended to give estimated coefficients of a similar magnitude, which aids the numerical stability of the estimation procedure. Specifically, population is divided by 1,000,000, and distance by 1,000. Throughout the paper, the scaling numbers are omitted when denoting the variables, and it must be kept in mind that they have been added to the regressions.

$$\text{Prob}(y = 1) = F \left( \beta_0 + \beta_1 \frac{Dist.}{1000} + \beta_2 \frac{Pop.}{1000000} \right).$$
Table 6: Results from Model 1.

The result of this first regression gives an $R^2$ of only 8%. This shows that modelling Southwest’s route presence only by accounting for distance and population is not sufficient, and falls far short in covering all of the relevant effects.

5.2 Model 2: Carriers and competitors

In this second step, data on competition is introduced, i.e. whether there are any other airlines operating on the same route. The variable Carrier is used, which gives the total number of airlines operating on the route, including Southwest. In the modelling itself, attention has to be given to the fact that to study the number of competitors, one has to subtract 1 from Carrier when Southwest operates. For example, if Carrier is equal to 6, and Southwest has operations on the route, then there are only 5 competitors. This has some effect on the way the data is treated.

$$\text{Prob}(y = 1) = F(\beta_0 + \beta_1 Dist. + \beta_2 Pop. + \beta_3 Comp.)$$
Table 7: Results from Model 2 without distinguishing between carrier and competitor.

<table>
<thead>
<tr>
<th></th>
<th>Coeff.</th>
<th>SE</th>
<th>Prob.</th>
<th>MEΦ</th>
<th>MEA</th>
<th>ME OR</th>
<th>RCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist.</td>
<td>-0.1335</td>
<td>0.0098</td>
<td>0.0000</td>
<td>-0.0667</td>
<td>-0.0334</td>
<td>0.8736</td>
<td>0%</td>
</tr>
<tr>
<td>Pop.</td>
<td>0.0832</td>
<td>0.0078</td>
<td>0.0000</td>
<td>0.0416</td>
<td>0.0208</td>
<td>1.0850</td>
<td>6%</td>
</tr>
<tr>
<td>Carrier</td>
<td>0.4470</td>
<td>0.0106</td>
<td>0.0000</td>
<td>0.2232</td>
<td>0.1118</td>
<td>1.5610</td>
<td>17%</td>
</tr>
<tr>
<td>R²</td>
<td>25%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>0.9983</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It can be seen that for the model results presented in Table 7, the R² increases considerably from 8% in Model 1 to 25%. This is caused by endogeneity: when a model of Southwest’s presence is estimated by accounting for number of carriers, we implicitly model Southwest’s presence (on the left hand side of the equation as a dependent variable), as a function of Southwest’s presence (as being part of the number of carriers serving a route). This ‘reverse causality’ can be investigated by a regression of the explanatory variable, here Carrier, on the dependent variable, here Southwest’s presence on a route Prob(y = 1). The R² of this regression is named the Reverse Causality Index (RCI). If endogeneity occurs, then RCI is relatively high, meaning that Carrier as an independent variable has a reasonable influence on the dependent variable Prob(y = 1). Table 7 gives an RCI of 17% for the Carrier variable. When Southwest’s presence is modelled by a variable which is strongly linked to Southwest’s presence, the R² for the model increases considerably, but has low explanatory power.

Therefore, a variable capturing competition on a route has to be built, which is independent of Southwest: the number of competitors (for Southwest) is used, rather than the number of carriers on route. The results are given in Table 8. The influence of competitors on a route has an influence on Southwest’s route
choice, as expected. However, the increase of $R^2$ of about 3% compared to Model 1 is more reasonable and the RCI only gives 4%.

\begin{table}
\begin{center}
\begin{tabular}{lrrrrrrr}
\hline
 & Coeff. & SE & Prob. & MEΦ & MEA & ME OR & RCI \\
\hline
Dist. & -0.0586 & 0.0071 & 0.0000 & -0.0314 & -0.0146 & 1.0344 & 0\% \\
Pop. & 0.1552 & 0.0078 & 0.0000 & 0.0833 & 0.0387 & 1.2809 & 6\% \\
Comp. & 0.1792 & 0.0110 & 0.0000 & 0.0962 & 0.0447 & 1.3120 & 4\% \\
\hline
$R^2$ & \textbf{11\%} \\
OR & \textbf{1.0968} \\
\hline
\end{tabular}
\end{center}
\end{table}

Table 8: Results from Model 2 with the number of carriers replaced by the number of competitors.

5.3 \textit{Model 3: Competitors and quadratic terms}

In this part, the quadratic terms are added to allow for some nonlinearity within the model. Additionally, it must be investigated whether there is correlation between number of competitors, derived in Model 2, and the population.

\[
\text{Prob}(y = 1) = F(\beta_0 + \beta_1 D_{\text{ist}} + \beta_2 D_{\text{ist}}^2 + \beta_3 D_{\text{pop}} + \beta_4 D_{\text{pop}}^2 + \beta_5 D_{\text{comp}} + \beta_6 D_{\text{comp}}^2)
\]

The covariance data matrix in Table 9 gives a value of 38% for the correlation between population and the number of competitors. This correlation is created due to the fact that a route pair combining two cities with a high population should create a big market for airlines. The large size of the market may attract many airlines, which means that there is correlation: two of the variables which influence Southwest's route presence, population and number of competitors, are linked and therefore contain to a certain extent the same information.

An auxiliary regression of number of competitors on population eliminates the effect of correlation, resulting in a reduced correlation coefficient of less than
Due to the introduction of quadratic terms for population and number of competitors, correlation must also be controlled for in this case. As given in Table 12, correlation occurs a second time for the quadratic number of competitors and both population and the squared value of population. With the results of the second auxiliary regression given in Table 13, regression for Model 4 are given in Table 14.

<table>
<thead>
<tr>
<th>Coef.</th>
<th>SE</th>
<th>Prob.</th>
<th>ME/Phi</th>
<th>MEA</th>
<th>ME/ OR</th>
<th>RCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist.</td>
<td>-0.0586</td>
<td>0.0071</td>
<td>0.0000</td>
<td>-0.0308</td>
<td>-0.0146</td>
<td>0%</td>
</tr>
<tr>
<td>Pop.</td>
<td>0.1998</td>
<td>0.0071</td>
<td>0.0000</td>
<td>0.1052</td>
<td>0.0498</td>
<td>1.5552</td>
</tr>
<tr>
<td>Comp. *2</td>
<td>0.1792</td>
<td>0.0110</td>
<td>0.0000</td>
<td>0.0943</td>
<td>0.0447</td>
<td>1.5243</td>
</tr>
</tbody>
</table>

Table 11: Results for Model 3 without quadratic terms.
### Table 12: Covariance data matrix for Model 3 with quadratic terms, before second auxiliary regression.

<table>
<thead>
<tr>
<th></th>
<th>Dist.</th>
<th>Dist.$^2$</th>
<th>Pop.</th>
<th>Pop.$^2$</th>
<th>Comp.*</th>
<th>Comp.$^{*2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist.</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dist.$^2$</td>
<td>0.9364</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pop.</td>
<td>0.001008</td>
<td>-0.0207</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pop.$^2$</td>
<td>0.0096</td>
<td>0.0008</td>
<td>0.8610</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp.*</td>
<td>0.1388</td>
<td>0.1093</td>
<td>5.86E-16</td>
<td>-0.1314</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>Comp.$^{*2}$</td>
<td>0.1321</td>
<td>0.1100</td>
<td>0.4354</td>
<td>0.3544</td>
<td>0.6985</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

### Table 13: Covariance data matrix for Model 3 with quadratic terms, after second auxiliary regression.

<table>
<thead>
<tr>
<th></th>
<th>Dist.</th>
<th>Dist.$^2$</th>
<th>Pop.</th>
<th>Pop.$^2$</th>
<th>Comp.*</th>
<th>Comp.$^{*2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist.</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dist.$^2$</td>
<td>0.9364</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pop.</td>
<td>0.0011</td>
<td>-0.0207</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pop.$^2$</td>
<td>0.0096</td>
<td>0.0008</td>
<td>0.8610</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp.*</td>
<td>0.1388</td>
<td>0.1093</td>
<td>5.86E-16</td>
<td>-0.1314</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>Comp.$^{*2}$</td>
<td>0.1472</td>
<td>0.1340</td>
<td>1.96E-16</td>
<td>4.42E-16</td>
<td>0.7651</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Table 12: Covariance data matrix for Model 3 with quadratic terms, before second auxiliary regression.

Table 13: Covariance data matrix for Model 3 with quadratic terms, after second auxiliary regression.
Table 14: Results for Model 3 without quadratic terms, after second auxiliary regression.

5.4 Model 4: Commercial sectors

In the next step, the influence of regional economic factors is taken into account, introducing the dummy variables of Leisure and Business as the ratios of sector-specific GDP over total GDP.

\[
\text{Prob}(y = 1) = F(\beta_0 + \beta_1 \text{Dist.} + \beta_2 \text{Dist.}^2 + \beta_3 \text{Pop.} + \beta_4 \text{Pop}^2 + \beta_5 \text{Comp.} + \beta_6 \text{Comp.}^2 + \beta_7 \text{Leisure} + \beta_8 \text{Business})
\]

5.5 Model 5: Traffic corridors

The introduction of traffic corridors should give additional explanatory power to the model by allocating airports to certain regions. This assignment creates five traffic areas, and their connections create 15 traffic corridors. These new
Table 15: Results of Model 4.

variables account for an increase in $R^2$ of 6%.

$$
\text{Prob}(y = 1) = F(\beta_0 + \beta_1\text{Dist} + \beta_2\text{Dist}^2 \\
+ \beta_3\text{Pop} + \beta_4\text{Pop}^2 + \beta_5\text{Comp} + \beta_6\text{Comp}^2 \\
+ \beta_7\text{Leisure} + \beta_8\text{Business} + \sum_{i=1}^{14} \beta_{i+8}\text{Region}_i)
$$

continued on next page
5.6 Model 6: Significance of airports

\[
\text{Prob}(y = 1) = F(\beta_0 + \beta_1 Dist. + \beta_2 Dist^2
+ \beta_3 \text{Pop.} + \beta_4 \text{Pop}^2 + \beta_5 \text{Comp.} + \beta_6 \text{Comp.}^2
+ \beta_7 \text{Leisure} + \beta_8 \text{Business} + \sum_{i=1}^{14} \beta_{i+8} \text{Region}_i
+ \sum_{i=2}^{14} \beta_{2i+1} \text{SW Hub}_i + \beta_{26} \text{AA Hub} + \beta_{27} \text{US Hub}
+ \beta_{28} \text{UA Hub} + \beta_{31} \text{CO Hub})
\]

<table>
<thead>
<tr>
<th>Region</th>
<th>Coeff.</th>
<th>SE</th>
<th>Prob.</th>
<th>MEΦ</th>
<th>MEA</th>
<th>ME OR</th>
<th>RCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>1.0736</td>
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<td>0.0000</td>
<td>0.9363</td>
<td>0.0864</td>
<td>90.5901</td>
<td>0%</td>
</tr>
<tr>
<td>9</td>
<td>0.4641</td>
<td>0.1297</td>
<td>0.0003</td>
<td>0.4048</td>
<td>0.0373</td>
<td>25.2268</td>
<td>0%</td>
</tr>
<tr>
<td>10</td>
<td>0.3733</td>
<td>0.1424</td>
<td>0.0087</td>
<td>0.3255</td>
<td>0.0300</td>
<td>21.8380</td>
<td>0%</td>
</tr>
<tr>
<td>11</td>
<td>0.8197</td>
<td>0.1470</td>
<td>0.0000</td>
<td>0.7150</td>
<td>0.0660</td>
<td>56.9782</td>
<td>0%</td>
</tr>
<tr>
<td>12</td>
<td>0.3253</td>
<td>0.1323</td>
<td>0.0139</td>
<td>0.2837</td>
<td>0.0262</td>
<td>19.5147</td>
<td>0%</td>
</tr>
<tr>
<td>13</td>
<td>0.9529</td>
<td>0.2276</td>
<td>0.0000</td>
<td>0.8311</td>
<td>0.0767</td>
<td>74.6156</td>
<td>0%</td>
</tr>
<tr>
<td>14</td>
<td>0.9720</td>
<td>0.1527</td>
<td>0.0000</td>
<td>0.8478</td>
<td>0.0782</td>
<td>75.2348</td>
<td>0%</td>
</tr>
</tbody>
</table>

\[R^2 = 28\%\]
\[\text{OR} = 10.3288\]

Table 16: Results of Model 3.

\[\text{continued on next page}\]
Table 17: Results of Model 6.

5.7 Model 7: Secondary airports

This model includes the estimated impact of secondary airports, \( Dist_{\leq 200 \text{km}} \), \( Hub_{0.50} \) and \( Hub_{50-100} \). As described in Section 3.4.2, accounting for secondary airports may explain an important part of the behaviour of a low-cost carrier like Southwest Airlines.
\[ Prob(y = 1) = F(\beta_0 + \beta_1 \text{Dist.} + \beta_2 \text{Dist}^2 + \beta_3 \text{Pop.} + \beta_4 \text{Pop}^2) \]
\[ + \beta_5 \text{Comp.} + \beta_6 \text{Comp.}^2 + \beta_7 \text{Leisure} + \beta_8 \text{Business} \]
\[ + \sum_{i=1}^{14} \beta_{i+8} \text{Region}_i + \sum_{i=2}^{4} \beta_{21+i} \text{SW_Hub}_i + \beta_{26} \text{AA_Hub} \]
\[ + \beta_{27} \text{US_Hub} + \beta_{28} \text{UA_Hub} + \beta_{29} \text{NW_Hub} + \beta_{30} \text{DL_Hub} \]
\[ + \beta_{31} \text{CO_Hub} + \beta_{32} \text{Dist.} \leq 200 + \beta_{33} \text{Hub}_{0.50} + \beta_{34} \text{Hub}_{50.100} \]

<table>
<thead>
<tr>
<th></th>
<th>Coeff.</th>
<th>SE</th>
<th>Prob.</th>
<th>MEΦ</th>
<th>MEA</th>
<th>ME OR</th>
<th>RCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist.</td>
<td>0.2464</td>
<td>0.0686</td>
<td>0.0003</td>
<td>0.2194</td>
<td>0.0186</td>
<td>17.7365</td>
<td>0%</td>
</tr>
<tr>
<td>Dist.</td>
<td>-0.0954</td>
<td>0.0139</td>
<td>0.0000</td>
<td>-0.0850</td>
<td>-0.0072</td>
<td>9.2726</td>
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</tr>
<tr>
<td>Pop.</td>
<td>0.6737</td>
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<td>0.0508</td>
<td>46.9860</td>
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</tr>
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<td>Pop.²</td>
<td>-0.0439</td>
<td>0.0073</td>
<td>0.0000</td>
<td>-0.0391</td>
<td>-0.0033</td>
<td>10.0092</td>
<td>1%</td>
</tr>
<tr>
<td>Comp.</td>
<td>0.3843</td>
<td>0.0333</td>
<td>0.0000</td>
<td>0.3423</td>
<td>0.0290</td>
<td>25.4824</td>
<td>1%</td>
</tr>
<tr>
<td>Comp²</td>
<td>-0.0765</td>
<td>0.0105</td>
<td>0.0000</td>
<td>-0.0681</td>
<td>-0.0058</td>
<td>9.3245</td>
<td>0%</td>
</tr>
<tr>
<td>Leisure</td>
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<td>0.0491</td>
<td>0.0000</td>
<td>0.0387</td>
<td>0.0033</td>
<td>11.3962</td>
<td>0%</td>
</tr>
<tr>
<td>Business</td>
<td>0.6228</td>
<td>0.0479</td>
<td>0.0000</td>
<td>0.5548</td>
<td>0.0470</td>
<td>34.3304</td>
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</tr>
<tr>
<td>Region1</td>
<td>1.7457</td>
<td>0.1530</td>
<td>0.0000</td>
<td>1.5549</td>
<td>0.1317</td>
<td>309.9745</td>
<td>3%</td>
</tr>
<tr>
<td>Region2</td>
<td>1.3423</td>
<td>0.1540</td>
<td>0.0000</td>
<td>1.1956</td>
<td>0.1013</td>
<td>150.5438</td>
<td>0%</td>
</tr>
<tr>
<td>Region3</td>
<td>1.1885</td>
<td>0.1546</td>
<td>0.0000</td>
<td>1.0587</td>
<td>0.0897</td>
<td>114.3534</td>
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</tr>
<tr>
<td>Region4</td>
<td>1.2497</td>
<td>0.1621</td>
<td>0.0000</td>
<td>1.1132</td>
<td>0.0943</td>
<td>127.3877</td>
<td>0%</td>
</tr>
<tr>
<td>Region5</td>
<td>1.1554</td>
<td>0.1581</td>
<td>0.0000</td>
<td>0.9935</td>
<td>0.0841</td>
<td>96.6219</td>
<td>0%</td>
</tr>
<tr>
<td>Region6</td>
<td>0.8930</td>
<td>0.1611</td>
<td>0.0000</td>
<td>0.7954</td>
<td>0.0674</td>
<td>64.6034</td>
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<tr>
<td>Region7</td>
<td>0.9814</td>
<td>0.1545</td>
<td>0.0000</td>
<td>0.8742</td>
<td>0.0740</td>
<td>73.3247</td>
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</tr>
<tr>
<td>Region8</td>
<td>1.3561</td>
<td>0.1808</td>
<td>0.0000</td>
<td>1.2079</td>
<td>0.1203</td>
<td>172.2953</td>
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</tr>
<tr>
<td>Region9</td>
<td>0.6794</td>
<td>0.1551</td>
<td>0.0000</td>
<td>0.6052</td>
<td>0.0513</td>
<td>40.6086</td>
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<tr>
<td>Region10</td>
<td>0.8382</td>
<td>0.1755</td>
<td>0.0000</td>
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<td>0.0632</td>
<td>54.7984</td>
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<tr>
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<td>0.1801</td>
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<td>1.0171</td>
<td>0.0861</td>
<td>109.4376</td>
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<tr>
<td>Region12</td>
<td>0.5660</td>
<td>0.1590</td>
<td>0.0000</td>
<td>0.5041</td>
<td>0.0427</td>
<td>32.2130</td>
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<tr>
<td>Region13</td>
<td>1.1266</td>
<td>0.2761</td>
<td>0.0000</td>
<td>1.0035</td>
<td>0.0850</td>
<td>109.1417</td>
<td>0%</td>
</tr>
<tr>
<td>Region14</td>
<td>1.0691</td>
<td>0.1837</td>
<td>0.0000</td>
<td>0.9523</td>
<td>0.0807</td>
<td>95.4465</td>
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</tr>
<tr>
<td>SW_Hub_2</td>
<td>1.1675</td>
<td>0.1066</td>
<td>0.0000</td>
<td>1.0399</td>
<td>0.0881</td>
<td>138.0710</td>
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</tr>
<tr>
<td>SW_Hub_3</td>
<td>1.5641</td>
<td>0.1016</td>
<td>0.0000</td>
<td>1.3932</td>
<td>0.1180</td>
<td>299.6611</td>
<td>1%</td>
</tr>
<tr>
<td>SW_Hub_4</td>
<td>2.0134</td>
<td>0.0998</td>
<td>0.0000</td>
<td>1.7934</td>
<td>0.1519</td>
<td>715.3739</td>
<td>8%</td>
</tr>
<tr>
<td>AA_Hub</td>
<td>-0.7657</td>
<td>0.0677</td>
<td>0.0000</td>
<td>-0.6820</td>
<td>-0.0578</td>
<td>2.4099</td>
<td>0%</td>
</tr>
</tbody>
</table>

*continued on next page*
Table 18: Results of Model 7.

<table>
<thead>
<tr>
<th></th>
<th>Coeff.</th>
<th>SE</th>
<th>Prob.</th>
<th>MEΦ</th>
<th>MEA</th>
<th>ME OR</th>
<th>RCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>US_Hub</td>
<td>-0.1639</td>
<td>0.0844</td>
<td>0.0520</td>
<td>-0.1460</td>
<td>-0.0124</td>
<td>7.2754</td>
<td>0%</td>
</tr>
<tr>
<td>UA_Hub</td>
<td>-0.0844</td>
<td>0.0612</td>
<td>0.1683</td>
<td>-0.0751</td>
<td>-0.0064</td>
<td>9.1378</td>
<td>0%</td>
</tr>
<tr>
<td>NW_Hub</td>
<td>-0.6807</td>
<td>0.0691</td>
<td>0.0000</td>
<td>-0.6063</td>
<td>-0.0514</td>
<td>2.5708</td>
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</tr>
<tr>
<td>DL_Hub</td>
<td>-1.1106</td>
<td>0.0914</td>
<td>0.0000</td>
<td>-0.9893</td>
<td>-0.0838</td>
<td>1.1497</td>
<td>1%</td>
</tr>
<tr>
<td>CO_Hub</td>
<td>-0.7150</td>
<td>0.1107</td>
<td>0.0000</td>
<td>-0.6368</td>
<td>-0.0539</td>
<td>2.6243</td>
<td>0%</td>
</tr>
<tr>
<td>Dist. ≤ 200</td>
<td>-2.6026</td>
<td>0.6062</td>
<td>0.0000</td>
<td>-2.3182</td>
<td>-0.1963</td>
<td>0.0522</td>
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</tr>
<tr>
<td>Hub_0.50</td>
<td>-0.9726</td>
<td>0.0780</td>
<td>0.0000</td>
<td>-0.8663</td>
<td>-0.0734</td>
<td>1.4990</td>
<td>0%</td>
</tr>
<tr>
<td>Hub_50_100</td>
<td>0.1398</td>
<td>0.0582</td>
<td>0.0163</td>
<td>0.1245</td>
<td>0.0105</td>
<td>16.3324</td>
<td>2%</td>
</tr>
<tr>
<td>R²</td>
<td>51%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>11.1665</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.8 Model 8: Congestion effects

In this model the effects of congestion in form of delayed departures and arrivals, Max_DEP_Delay and Max_ARR_Delay are introduced. Once more, the effect of correlation must be controlled for, because a delayed arrival at an airport can cause a delay for the following departure.

\[
\text{Prob}(y = 1) = F(\beta_0 + \beta_1 \text{Dist.} + \beta_2 \text{Dist}^2 + \beta_3 \text{Pop.} + \beta_4 \text{Pop}^2 + \beta_5 \text{Comp.*} + \beta_6 \text{Comp.}*2 + \beta_7 \text{Leisure} + \beta_8 \text{Business} + \sum_{i=1}^{14} \beta_{i+8} \text{Region} + \sum_{i=2}^{4} \beta_{21+i} \text{SW_Hub}_i + \beta_{26} \text{AA_Hub} + \beta_{27} \text{US_Hub} + \beta_{28} \text{UA_Hub} + \beta_{29} \text{NW_Hub} + \beta_{30} \text{DL_Hub} + \beta_{31} \text{CO_Hub} + \beta_{32} \text{Dist.} \leq 200 + \beta_{33} \text{Hub}_0.50 + \beta_{34} \text{Hub}_50_100 + \beta_{35} \text{MAX_Delay})
\]

For the further modelling the impact of delays is captured by only taking
Table 19: Covariance data matrix for Model 8 before auxiliary regression.

<table>
<thead>
<tr>
<th></th>
<th>DEP_Delay</th>
<th>ARR_Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEP_Delay</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>ARR_Delay</td>
<td>0.6892</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

one congestion variable, MAX_Delay, which is the maximum of either delay or departure. The regression results for the new regression with a single delay parameter are given in Table 21.

Table 19 gives a correlation between the maximum of delayed departures and delayed arrivals of about 69%. Table 20 gives the regression result with the two variables Max DEP_Delay and Max ARR_Delay.

<table>
<thead>
<tr>
<th>Coeff.</th>
<th>SE</th>
<th>Prob.</th>
<th>ME Φ</th>
<th>MEA</th>
<th>ME OR</th>
<th>RCI</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.0001</td>
<td>0.0052</td>
<td>0.0084</td>
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</tr>
<tr>
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<td>-0.1071</td>
<td>0.0146</td>
<td>0.0000</td>
<td>-0.0020</td>
<td>-0.0033</td>
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<tr>
<td>Pop.</td>
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<td>0.0000</td>
<td>0.0124</td>
<td>0.0203</td>
<td>0.1308</td>
</tr>
<tr>
<td>Pop.²</td>
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<td>0.0068</td>
<td>0.0000</td>
<td>-0.0008</td>
<td>-0.0013</td>
<td>0.0295</td>
</tr>
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<td>0.0129</td>
<td>0.0781</td>
</tr>
<tr>
<td>Comp.²</td>
<td>-0.0824</td>
<td>0.0104</td>
<td>0.0000</td>
<td>-0.0015</td>
<td>-0.0025</td>
<td>0.0272</td>
</tr>
<tr>
<td>Leisure</td>
<td>-0.0580</td>
<td>0.0515</td>
<td>0.2599</td>
<td>-0.0011</td>
<td>-0.0018</td>
<td>0.0278</td>
</tr>
<tr>
<td>Business</td>
<td>0.5888</td>
<td>0.0482</td>
<td>0.0000</td>
<td>0.0111</td>
<td>0.0181</td>
<td>0.0945</td>
</tr>
<tr>
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<td>0.0251</td>
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<td>1.2498</td>
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<td>0.0000</td>
<td>0.0235</td>
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<td>Region3</td>
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<td>0.0000</td>
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<td>0.0293</td>
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</tr>
<tr>
<td>Region5</td>
<td>1.0636</td>
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<td>0.0000</td>
<td>0.0200</td>
<td>0.0326</td>
<td>0.2507</td>
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<tr>
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<td>0.8534</td>
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<td>0.0000</td>
<td>0.0160</td>
<td>0.0262</td>
<td>0.1690</td>
</tr>
<tr>
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<td>0.0000</td>
<td>0.0164</td>
<td>0.0268</td>
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<tr>
<td>Region8</td>
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<td>0.1857</td>
<td>0.0000</td>
<td>0.0223</td>
<td>0.0363</td>
<td>0.3543</td>
</tr>
<tr>
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<td>0.0000</td>
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<tr>
<td>Region10</td>
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<td>0.0001</td>
<td>0.0130</td>
<td>0.0212</td>
<td>0.1227</td>
</tr>
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<td>0.8833</td>
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<td>0.0000</td>
<td>0.0166</td>
<td>0.0271</td>
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</tr>
<tr>
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<td>0.0021</td>
<td>0.0093</td>
<td>0.0152</td>
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<td>0.0212</td>
<td>0.0347</td>
<td>0.3768</td>
</tr>
</tbody>
</table>

continued on next page
## Table 20: Results of Model 8.

<table>
<thead>
<tr>
<th>Coeff.</th>
<th>SE</th>
<th>Prob.</th>
<th>MEΦ</th>
<th>MEA</th>
<th>ME OR</th>
<th>RCI</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.0291</td>
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<td>0.0617</td>
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<td>-0.0381</td>
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</table>

R²: **53%**

OR: **0.033**

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<th>MEΦ</th>
<th>MEA</th>
<th>ME OR</th>
<th>RCI</th>
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<td>0.0000</td>
<td>-0.0048</td>
<td>-0.0062</td>
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<td>0.0297</td>
<td>0.0378</td>
<td>0.2576</td>
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<td>0.0000</td>
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<td>0.0404</td>
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<td>0.0382</td>
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<td>0.0517</td>
<td>0.3927</td>
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<td>0.0538</td>
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continued on next page
Table 21: Results of Model 8 after the auxiliary regression.

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<th>Prob.</th>
<th>MEΦ</th>
<th>MEA</th>
<th>ME OR</th>
<th>RCI</th>
</tr>
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<tbody>
<tr>
<td>SW_Hub_3</td>
<td>1.5821</td>
<td>0.1060</td>
<td>0.0000</td>
<td>0.0743</td>
<td>0.0944</td>
<td>1.8638</td>
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<tr>
<td>SW_Hub_4</td>
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<td>0.0000</td>
<td>0.0946</td>
<td>0.1202</td>
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<tr>
<td>AA_Hub</td>
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<td>0.0681</td>
<td>0.0000</td>
<td>-0.0359</td>
<td>-0.0457</td>
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<tr>
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<td>-0.0022</td>
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<td>-0.0317</td>
<td>-0.0402</td>
<td>0.0157</td>
<td>1%</td>
</tr>
<tr>
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<td>-0.0736</td>
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<td>0.0073</td>
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<td>-0.6139</td>
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\[ R^2 = 53\% \]
\[ OR = 0.0681 \]

5.9 Model 9: Low-cost carrier competition

As a final step, the last variable describing the potential influence of competition is introduced: the presence of one of the defined low-cost carriers, namely JetBlue, AirTran, Frontier and Alaska.
\[
\text{Prob}(y = 1) = F(\beta_0 + \beta_1 \text{Dist.} + \beta_2 \text{Dist}^2 + \beta_3 \text{Pop.} + \beta_4 \text{Pop}^2 + \beta_5 \text{Comp.}^* + \beta_6 \text{Comp.}^2 + \beta_7 \text{Leisure} + \beta_8 \text{Business} + \sum_{i=1}^{14} \beta_{i+8} \text{Region}i + \sum_{i=2}^{4} \beta_{21+i} \text{SW Hub}_i + \beta_{26} \text{AA Hub} + \beta_{27} \text{US Hub} + \beta_{28} \text{UA Hub} + \beta_{29} \text{NW Hub} + \beta_{30} \text{DL Hub} + \beta_{31} \text{CO Hub} + \beta_{32} \text{Dist.} \leq 200 + \beta_{33} \text{Hub}_{0.50} + \beta_{34} \text{Hub}_{50\_100} + \beta_{35} \text{MAX Delay} + \beta_{36} \text{Jetblue} + \beta_{37} \text{Airtran} + \beta_{38} \text{Frontier} + \beta_{39} \text{Alaska})
\]

<table>
<thead>
<tr>
<th></th>
<th>Coeff.</th>
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<th>Prob.</th>
<th>MEϕ</th>
<th>MEA</th>
<th>ME OR</th>
<th>RCI</th>
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<td>0.0107</td>
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<td>0.0031</td>
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<td>-0.0010</td>
<td>-0.0014</td>
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continued on next page
Table 22: Results of Model 9.

<table>
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<th>MEΦ</th>
<th>MEA</th>
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<td>0.0653</td>
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<td>AA_Hub</td>
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<td>-0.0080</td>
<td>-0.0115</td>
<td>0.0244</td>
<td>0%</td>
</tr>
<tr>
<td>NW_Hub</td>
<td>-0.6687</td>
<td>0.0747</td>
<td>0.0000</td>
<td>-0.0195</td>
<td>-0.0279</td>
<td>0.0104</td>
<td>1%</td>
</tr>
<tr>
<td>DL_Hub</td>
<td>-1.2884</td>
<td>0.1025</td>
<td>0.0000</td>
<td>-0.0375</td>
<td>-0.0537</td>
<td>0.0032</td>
<td>1%</td>
</tr>
<tr>
<td>CO_Hub</td>
<td>-0.6573</td>
<td>0.1157</td>
<td>0.0000</td>
<td>-0.0191</td>
<td>-0.0274</td>
<td>0.0120</td>
<td>0%</td>
</tr>
<tr>
<td>Dist.$\leq$200</td>
<td>-2.7550</td>
<td>0.6696</td>
<td>0.0000</td>
<td>-0.0802</td>
<td>-0.1149</td>
<td>0.0001</td>
<td>0%</td>
</tr>
<tr>
<td>Hub_0_50</td>
<td>-0.8027</td>
<td>0.0760</td>
<td>0.0000</td>
<td>-0.0234</td>
<td>-0.0335</td>
<td>0.0090</td>
<td>0%</td>
</tr>
<tr>
<td>Hub_50_100</td>
<td>0.1809</td>
<td>0.0613</td>
<td>0.0032</td>
<td>0.0053</td>
<td>0.0075</td>
<td>0.0747</td>
<td>2%</td>
</tr>
<tr>
<td>MAX_Delay</td>
<td>-10.915</td>
<td>0.5820</td>
<td>0.0000</td>
<td>-0.3177</td>
<td>-0.4552</td>
<td>0.0000</td>
<td>3%</td>
</tr>
<tr>
<td>Jetblue</td>
<td>0.3387</td>
<td>0.0414</td>
<td>0.0000</td>
<td>0.0099</td>
<td>0.0141</td>
<td>0.0784</td>
<td>4%</td>
</tr>
<tr>
<td>Airtran</td>
<td>0.0012</td>
<td>0.0006</td>
<td>0.0528</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0457</td>
<td>0%</td>
</tr>
<tr>
<td>Frontier</td>
<td>0.0051</td>
<td>0.0007</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0461</td>
<td>1%</td>
</tr>
<tr>
<td>Alaska</td>
<td>0.0025</td>
<td>0.0004</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0458</td>
<td>2%</td>
</tr>
</tbody>
</table>

Unsuccessful Variables: Other variables were added to the model without success. The first effect that could not be measured is the use of a substitute airport. The idea was to create a dummy variable that gave information on the presence of a secondary airport close to a hub. The intuition is that Southwest would have preferred a secondary, cheaper and less congested airport for its operations. These variables turned out to be insignificant in our model. It is probably due to a poor specification of the variables, as it is quite difficult to create a variable that measures exactly the effect of a substitute airport.

The second type of variables that were not successfully added are network specific variables. For example, a dummy variable accounting for the Wright
Amendment was added to exclude some routes that cannot be served out of Dallas Love Field (DAL). The problem is that this variable had too many zeroes, introducing some collinearity with the constant in the regression. More thought can be given on how to introduce these network specificities into the model.

6 Model interpretation

In the previous part we created the model, adding variables step-by-step to get an $R^2$ as high as possible. In this section, the objective is to study the results when applying this model to the entire dataset, quarter-by-quarter.

6.1 Adapting the model to the dataset

When applying the code to the entire dataset, some errors occur. The first issue concerns the two variables UA_Hub and US_Hub. The model cannot distinguish between the values 0 or 1. These two variables are dropped for the analysis. Also, the regression fails for some quarters because the Dist.$<=$200 (km) is too restrictive. It is therefore increased to 300km. The regression works once these changes are made. It then appears that the estimated parameter $\hat{\beta}$ for the variable MAX_Delay has a much larger value than the others. MAX_Delay is therefore scaled in the model to guarantee coefficients of similar magnitudes. This concludes the changes that have to be made to the model.
6.2 Interpretation of the results

6.2.1 Initial analysis

The model we estimated for 2007:4 remains quite good for 2002 to 2006. The model is relatively robust as $R^2$ remains quite high, around 55% for all quarters.

The estimated parameters $\hat{\beta}$ are plotted below on Figure 6. The numbers 5, 10, 15 and 20 on the X-axis represent the quarters. For example, quarter 15 refers to 2005:3. Several variables seem to switch between the fourth and the fifth quarters. These variables include Region1, Region4, Region5, Region13, NW_Hub and MAX_Delay. On first reflection, this shift suggests the model is capturing a change in Southwest’s strategy. Estimated parameters $\hat{\beta}$ are
plotted a second time with a scaled y-axis in Figure [7] to measure the change in magnitude. MAX_Delay has a negative shift of 600% from -0.3 to -2.2. When trying to get the best fit, the model shows some variables follow MAX_Delay’s shift which would mean correlation between variables. This idea is rejected after inspecting the data correlation matrix: none of the variables that shift are correlated with MAX_Delay.
Figure 6: $\hat{\beta}$ value for all variables (unfiltered data). The X-axis counts the quarters: quarter 15 is 2005:3.
Figure 7: $\hat{\beta}$ value for all variables on a normalized y-axis (unfiltered data). Allows comparison of relative magnitudes.
This coefficient shift means routes that have high delay are not being served as much as before: Southwest became very concerned by congestion issues between 2002:4 and 2003:1. Does this mean a change in strategy? The answer should come from the data. If the answer is yes then either a complete re-organization of Southwest’s network to avoided crowded routes took place, or airports served by Southwest suddenly get less congested. The former seems more plausible but 67 changes of routes, both new routes and routes that no longer exist, took place between 2002:4 and 2003:1, which accounts for a 5% change in the 1461 total routes. This is not really a significant network change, so not a valid explanation for MAX_Delay’s break. Moreover, the average MAX_Delay for routes served (not served) is 19% (19%) in 2002:4 and 16% (21%) in 2003:3, which shows that Southwest is clearly serving fewer routes that are congested. This is illustrated in Figure 8.

Figure 8: MAX_Delay plotted across the 1461 routes served in 2002 (grey) and 2003(black). Notice delay is shorter for routes served in 2003.
To specifically evaluate how this affects Southwest’s presence, we would normally look at the marginal effects of each variable. In this case, marginal effects are difficult to analyze because they are all equal to zero. This comes as no surprise: marginal effects are worth $\phi(x'\beta)\beta$ for the probit model. The argument in the probability density function is the product of the mean-values by the estimated parameters. For MAX_Delay, this product decreases from -0.5 to -4.5. The value of the normal probability distribution function is extremely low: $\phi(-4.5) = 0.0000001$. Thus marginal effects are strange to interpret, any change in the variables would have absolutely no influence on Southwest’s presence. To sum up, MAX_Delay is changing greatly from 2002 to 2003. It is hard to understand what is really going and saying none of the variables has an effect on Southwest’s presence seems absurd, especially as $R^2$ remains high.

6.2.2 Marginal effects

Regional variables: For 2004 and 2005, we can interpret the marginal effects of each variable on Southwest’s presence as seen in Figure 6.2.2. In 2005:2, an increase of 0.1 points of Region5 increases the probability of Southwest’s presence by 2.7 points, bearing in mind region5 counts the number of NE-SW routes. Mathematically, an increase of 0.1 point of Region5 represents about 25 new routes because the mean of Region5 is 2484. In real life though, the only way to open new routes is by creating new airports. So the number of NE-SW routes is constant across the dataset, no airports are created. To make things clear, the number of NE-SW routes remains constant and would be costly to change (new airport). What this marginal effect means in real life is that Southwest is very attracted by connecting the NE and SW regions. Indeed, the SW region
Figure 9: Marginal effects for years 2004 and 2005. Top to bottom: Region5, Population, AA_Hub. On the x-axis, number 6 represents 2005:2.

includes densely populated MSAs (Los Angeles, Dallas, Houston) and so does the NE region (New York, Boston, Philadelphia).

<table>
<thead>
<tr>
<th>Region code</th>
<th>Regions</th>
<th>Marginal effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Region1</td>
<td>SW_SW</td>
</tr>
<tr>
<td>2.</td>
<td>Region8</td>
<td>SE_NW</td>
</tr>
<tr>
<td>3.</td>
<td>Region2</td>
<td>SW_SE</td>
</tr>
</tbody>
</table>

Table 23: Top three regions Southwest wants to connect based on 2005Q2.
<table>
<thead>
<tr>
<th>Region code</th>
<th>Regions</th>
<th>Marginal effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.</td>
<td>Region6</td>
<td>SE, SE</td>
</tr>
<tr>
<td>14.</td>
<td>Region9</td>
<td>SE, NE</td>
</tr>
<tr>
<td>15.</td>
<td>Region12</td>
<td>MW, NE</td>
</tr>
</tbody>
</table>

Table 24: Last three regions Southwest wants to connect based on 2005Q2.

Other variables for 2005:2: An increase of 0.1 points of population increases the probability of Southwest’s presence by 1.9 points. This means densely populated areas have a positive marginal effect on Southwest’s presence. To give a rough idea, an increase of population of 0.1 point represents 9,500 inhabitants.

An increase of 0.1 points of AA_Hub decreases the probability of Southwest’s presence by 1.3 points. The negative marginal effect means that Southwest avoids having routes which have one of American Airlines’ hubs at an endpoint. It could also mean American Airlines is avoiding having hubs where Southwest operates but given the investment it represents to set up or move a hub, it is very unlikely American Airlines is placing its hubs to avoid Southwest. In any case, the model is suggesting something is happening between American Airlines’ hubs and Southwest’s strategy.

AirTran, Frontier and Alaska have very little marginal effect on Southwest’s presence on the route across the dataset. JetBlue however has a strong positive marginal effect which suggests either Southwest is attacking JetBlue, or JetBlue is attacking Southwest. Again, the model is saying something is going on between Southwest and JetBlue; a dynamic approach with details on pricing policies would definitely give more details on the nature of the competition between these two carriers.

Interpretation of the marginal effects for 2003, 2006 and 2007 is more difficult
Figure 10: Marginal effects of other low-cost carriers. JetBlue’s presence seems to have a significant effect on Southwest’s presence. Possible battle between these two carriers.
for the reasons we mentioned in 6.2.1, MAX_Delay is changing greatly from 2002 to 2003 hence pushing the marginal effect of all variables to almost zero.

6.3 Filtered data

Filtered data allows to exclude most of the routes that have one stop. Without going into details, we simply increased the passenger threshold for each route, in order to account for a certain distinction between nonstop and one-stop flights. A reasonable attempt to so is the introduction a threshold for passenger numbers. City-pairs with passenger numbers below that threshold are supposed to be one-stop connections, otherwise nonstop connections. The DOT database reports flights on the base of O-and D-markets and does not take eventual stopovers (one-stop flights) into account. To identify a certain number of one-stop flights, it is supposed that only flights above a certain number of passengers are served as nonstop flights. This threshold is set to be 90 (minimum number of passengers per quarter in the dataset, corresponding to 900 passengers per quarter in reality). Southwest now has fewer routes in our model, but most of these routes are served by not non-stop flights. The code works for all quarters except 2007:3. The model is unable to find an optimum when running the maximum likelihood algorithm. This is due to a poorly conditioned objective surface for 2007:3. It is hard to understand why this is happening for just one quarter. We will therefore decide to exclude this quarter from our results.
Figure 11: Graph showing the value of the estimated parameters for the unfiltered data.

Figure 12: Graph showing the value of the estimated parameters for the filtered data. 2007:3 and 2007:4 are missing because of an error in the regression. Results are similar to the unfiltered data.
Figure 13: $R^2$ remains quite high for the filtered data which shows some robustness in the model.

This data represents a test of robustness for our code, most of the results seen on Figures 14 and 16 show similar results for both filtered and non-filtered data. The $R^2$ plot graph is corrected for 2007 by averaging the first, second and fourth quarter.

Notice the relative magnitude of the marginal effects on the unfiltered data is greater. This suggests a change in the variables has more impact on Southwest’s presence. MAX_Delay is shifting again at the end of 2002 for the same reasons as we saw before.

To sum up, filtered data is used to take a closer look at only the non-stop routes. The model manages to fit the data quite well and results are pretty similar. The results are generally the same with some interesting differences, Region14 is insignificant which proves Southwest is not interested in connecting
Figure 14: Marginal effects for the unfiltered data.

Figure 15: Marginal effects for the unfiltered data. Decrease in magnitude of the coefficients suggests the variables have more impact on Southwest’s presence.
Figure 16: Output of the regression for the filtered data. Magnitude similar to the non-filtered model.
the North East and the center-region with non stop flights. Presence of competitor or competitor's hub has virtually no impact on Southwest. Maybe because they are the most competitive on non-stop flights.

6.3.1 Entire dataset

In this section, the data used is made of the twenty-four aggregated data files. What is the difference? The model is now making one big regression on all the data instead of twenty-four smaller ones. This is done for two reasons. First, this is a robustness test for the model. The data is not identical per say, so the model will have to find the best fit for the variables from 2002:1 to 2007:4. This allows to see how the model copes with various types of data. Second, this allows to interpret the data as a whole, looking at Southwest's presence over six years. The results remain good as $R^2$ is worth 52%. General results are similar to those we saw before which is what one would expect. Two variables become insignificant, Region9 and Region12 which suggests Southwest didn't really care about connecting the associated regions. Concerning marginal effects, two variables stand out, SW_Hub_4 has the greatest positive effect whereas Dist.$\leq$200 has the greatest negative effect. This means Southwest is more interested in connecting its focus cities avoiding routes that are too short.
<table>
<thead>
<tr>
<th></th>
<th>Coeff.</th>
<th>SE</th>
<th>Prob.</th>
<th>MEφ</th>
<th>MEA</th>
<th>ME OR</th>
<th>RCI</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
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<td>Dist.</td>
<td>0.1662</td>
<td>0.0154</td>
<td>0.0000</td>
<td>0.0184</td>
<td>0.0126</td>
<td>0.1251</td>
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<td>2.0739</td>
</tr>
<tr>
<td>Dist.²</td>
<td>-0.0911</td>
<td>0.0032</td>
<td>0.0000</td>
<td>-0.0101</td>
<td>-0.0069</td>
<td>0.0750</td>
<td>0%</td>
<td>6.7352</td>
</tr>
<tr>
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<td>0.0000</td>
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<td>0.0457</td>
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<td>0.9532</td>
</tr>
<tr>
<td>Pop²</td>
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<td>0.0000</td>
<td>-0.0042</td>
<td>-0.0029</td>
<td>0.0822</td>
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<td>3.1948</td>
</tr>
<tr>
<td>Comp.²</td>
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<td>0.0066</td>
<td>0.0000</td>
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<td>0.0231</td>
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</tr>
<tr>
<td>Comp.²*²</td>
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<td>0.0000</td>
<td>-0.0074</td>
<td>-0.0051</td>
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<td>0.0000</td>
</tr>
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</tr>
<tr>
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<td>0.0346</td>
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<td>0.1178</td>
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<td>0.0330</td>
<td>0.0226</td>
<td>0.1461</td>
<td>0%</td>
<td>0.1101</td>
</tr>
<tr>
<td>Region4</td>
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<td>0.0228</td>
<td>0.1488</td>
<td>0%</td>
<td>0.0367</td>
</tr>
<tr>
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</tr>
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<td>0.0295</td>
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<td>0.1243</td>
</tr>
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<td>0.0000</td>
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<td>0.2766</td>
<td>0%</td>
<td>0.0414</td>
</tr>
<tr>
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<td>0.0658</td>
<td>0.0595</td>
<td>0.2687</td>
<td>0.0073</td>
<td>0.0050</td>
<td>0.0904</td>
<td>0%</td>
<td>0.1003</td>
</tr>
<tr>
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<td>0.0616</td>
<td>0.0000</td>
<td>0.0337</td>
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<td>0%</td>
<td>0.0571</td>
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<td>0.3264</td>
<td>0.0602</td>
<td>0.0000</td>
<td>0.0361</td>
<td>0.0247</td>
<td>0.1669</td>
<td>0%</td>
<td>0.0387</td>
</tr>
<tr>
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<td>0.0600</td>
<td>0.6910</td>
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<td>-0.0018</td>
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<td>0%</td>
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<td>0.0000</td>
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<td>0.0223</td>
<td>0.1583</td>
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<td>0.0661</td>
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<td>0.0000</td>
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<td>0.0000</td>
<td>0.1939</td>
<td>0.1330</td>
<td>3.1892</td>
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<td>AA_Hub</td>
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<td>0.0000</td>
<td>-0.0854</td>
<td>-0.0586</td>
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<td>0%</td>
<td>0.1958</td>
</tr>
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<td>0.0000</td>
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<td>-0.0389</td>
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<td>0.5088</td>
</tr>
<tr>
<td>MAX_Delay</td>
<td>-0.5271</td>
<td>0.0088</td>
<td>0.0000</td>
<td>-0.0582</td>
<td>-0.0400</td>
<td>0.0345</td>
<td>0%</td>
<td>2.3394</td>
</tr>
<tr>
<td>Jetblue</td>
<td>0.3919</td>
<td>0.0087</td>
<td>0.0000</td>
<td>0.0433</td>
<td>0.0297</td>
<td>0.1841</td>
<td>0%</td>
<td>0.2367</td>
</tr>
<tr>
<td>Airtran</td>
<td>-0.0018</td>
<td>0.0002</td>
<td>0.0000</td>
<td>-0.0002</td>
<td>-0.0001</td>
<td>0.0097</td>
<td>2%</td>
<td>5.6122</td>
</tr>
<tr>
<td>Frontier</td>
<td>0.0021</td>
<td>0.0002</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0905</td>
<td>3%</td>
<td>3.6983</td>
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<tr>
<td>Alaska</td>
<td>0.0020</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0904</td>
<td>0%</td>
<td>7.9095</td>
</tr>
</tbody>
</table>

R²: 52%
OR: 0.0901

Table 25: Results of the entire dataset.
6.4 Southwest performance

In this section, we are looking for possible relations between Southwest’s financial performance and their network changes. Does Southwest open more routes when they have better results?

Quarterly data on Southwest’s performance can be found on their website. Some key financial variables are used as indicators of Southwest’s performance in the short-term, mid-term and long-term.

- Three variables are used to account for Southwest’s short term performance. Net Income gives an idea of the profit made on a quarterly basis. Available Seat Mile (ASM), Fuel and oil expenses are two variables used to measure short-term costs. Fuel and Oil expenses depends on the number of flights, so it is divided by ASM to get a raw indicator. This new variable represents short-term costs.

- Total current liabilities and total current assets are used as mid-term/long-term indicators. The six years covered by our dataset is just starting to be long-term decisions. Total liabilities divided by total assets is used as a mid-term/long-term indicator.

These indicators are scaled then plotted with the number of changes in the network. A change in the network is either a route being served or a route that Southwest stops serving. A positive change is a network expansion. A negative change is a network contraction. The results are shown on Figure [17]
Figure 17: Performance indicators are plotted, the darker curves show net income and route changes seem to be correlated.

The graph shows that the number of changes in the network is linked to the net income. A look at the data correlation matrix shows high correlation between the change in network and Net income. This would suggest Southwest’s strategy for the route network is based on short term decisions, whether the route is profitable. Longer-term strategies may be revealed either with a longer time period or maybe using other variables that represent long-term performance like long term debt less current maturities.

<table>
<thead>
<tr>
<th></th>
<th>Change</th>
<th>Net Income</th>
<th>Fuel/ASM</th>
<th>Liabilities/Assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change</td>
<td>1,0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Income</td>
<td>0,7001</td>
<td>1,0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel/ASM</td>
<td>-0,0056</td>
<td>0,2466</td>
<td>1,0000</td>
<td></td>
</tr>
<tr>
<td>Liabilities/Assets</td>
<td>-0,1795</td>
<td>-0,3114</td>
<td>-0,8082</td>
<td>1,0000</td>
</tr>
</tbody>
</table>

Table 26: Correlation between performance variables. Coefficient very high for change and Net Income.
6.5 Verification of the model

The regression results of 2007:4 are compared to the current Southwest network in terms of nonstop connections. The objective is to test whether the model has some predictive capacity. Figures 19 and 18 demonstrate the general estimation results for the route presence of Southwest for 2007:4. During this period Southwest was present on 1837 nonstop and one-stop routes; during the same period 27,966 routes have been identified that Southwest was not on. As seen in Figure 18 the model estimates for about half of the routes Southwest was actually serving, a reasonably high probability of presence, of more than 50%.

Figure 18: Fitted probabilities for Southwest’s presence.
For the routes not being served, shown in Figure 19, the model tells quite well that the vast majority of these routes have indeed a low estimated probability. The increased proportion of probability, in the range between 0 and 2000, simply says that once Southwest is in an airport, even the probability of routes not served out of this airport rise.

Figure 19: Fitted probabilities for Southwest not being present.
For the practical demonstration of the model, applied on Southwest’s actual network, a difference is made between three types of airports:

- Airports where Southwest announced entry and did not have any operations before: LGA and MSP, Figures 20 and 21.

- Airports that Southwest serves and has recently announced an increase in service. The assumption of an increase of service at these airports is based on an announcement made by Southwest in December 2008. The increase is not specified, but can be realized in terms of new added destinations and/or increase in frequencies on existing routes. Namely, these airports are MDW, DEN, BNA and LAX, Figures 22, 23, 24 and 25.

- Airports that Southwest serves but has not recently announced an increase in service. In contrast to the above, some airports not mentioned in this announcement are assumed not to experience a significant expansion of Southwest operations. The following airports are taken as an example: SFO and DTW, Figures 26 and 27.

The base for the verification of the model and the comparison of different outputs, the regression results of 2007:Q4 are used. The selected probabilities shown in Figures 20 to 27 refer to the highest calculated probabilities for Southwest’s presence for nonstop routes where Southwest was not present, at least during 2007:Q4.
Contrary to an LCC’s aim of efficiently saving times on ground, Southwest will enter LGA, being one of U.S.’s most congested airports [36]. Within the range of the 15 nonstop connections of the highest probability, the best value only gives 30%. These low probabilities can be caused by the strong influence of the congestion variable in the model. So, even if Southwest enters LGA, it is generally concerned about airport congestion. Additionally, the presence of both Major carriers and other LCCs, notably JetBlue Airways (See Table 33), at LGA, may result in a strong competition at this airport.

![Figure 20: Fitted probabilities for routes from/to LGA.](image.png)
For the routes out of the new destination MSP, the model estimates a route to BUR being the most likely, though MSP will be served only from MDW \[2\]. Nevertheless, the model clearly predicts that the 15 most likely services out of MSP see a reasonable higher probability than those out of LGA. Whereas the probability of the possible routes at LGA shows a fast decrease to below 20% after a short time, MSP’s estimated routes give an average higher likelihood. MSP is neither a congested nor a slot restricted airport which may contribute to a better on-time performance for an airline.

![Figure 21: Fitted probabilities for routes from/to MSP.](image)
MDW as one of Southwest’s focus airports does already provide a large number of nonstop connections (see Table 2). The model estimates that missing nonstop connections to Florida (PBI and JAX) are likely to be served in the near future. Regarding the route between MDW and DAL, one effect becomes obvious: the political issue of the Wright Amendment cannot be reflected by the model. Nevertheless, the model estimates that there might be huge demand for nonstop connections between these two Southwest focus airports, even though they cannot be offered due to political reasons. In accordance to the announcement of Southwest airlines to increase services out of DEN, BNA and LAX, where the airline currently does not offer as many nonstop connections as out of MDW, the model predicts a set of possible nonstop connections with a high probability of presence. DEN offers nine connections with a probability of over 90% where Southwest should be present. As seen for the possible routes out of MDW in Figure 22, the model gives a high probability for services to DAL from DEN, BNA and LAX.

Figure 22: Fitted probabilities for routes from/to MDW.
Figure 23: Fitted probabilities for routes from/to DEN.

Figure 24: Fitted probabilities for routes from/to BNA.
Figures 25 and 26 serve as an example to demonstrate estimated probabilities for a route entry at common airports of the Southwest and at airports, where expansion is explicitly announced. The estimation results show for both DTW and SFO very high percentages for the first connections, but then decays very quickly. The maximum variation in probability for the announced airports within the first ten airport pairs is about 20% (for BNA), whereas this variation at the airports without significant expansion is between 30 (for DTW) and 40% (for SFO). Furthermore, by comparing the three groups of estimation results for Southwest’s presence on a certain route, it stands out that the probabilities may depend on Southwest’s presence at an airport. Generally speaking, once Southwest is present at an airport, either an airport like SFO or an airport like DEN, the probabilities of entering new nonstop services are significantly higher than for airports where Southwest is initially entering.
Figure 26: Fitted probabilities for routes from/to SFO.

Figure 27: Fitted probabilities for routes from/to DTW.
7 Conclusion

The objective of this paper was to research which parameters are driving Southwest Airlines’ presence on a given route. The first step consisted in getting some intuition, by gathering information from different sources. For example, it was likely that the presence of competitors on the route would have an impact. To get a quantified idea of the impact of some parameters, a thorough search for relevant databases is carried out in step two. The final step allows to create a model based on regressions to explain Southwest’s presence.

The model is working well at explaining why Southwest is present. It is generally looking at how demand is contributing via population and GDP. It manages to capture 22% of why Southwest is present. It then includes data on the structure of the network through region and hub-specific dummy variables. This increases the model’s quality to 48%. Finally, the input of new data and tweaking of the model allowed to capture about 55% of what is happening. This figure is relatively high for a presence model.

The model cannot be used to perform a dynamic forecast but it can be used for a static forecast. This gives an idea of where to look to study Southwest’s strategy. For example, it appears Southwest became concerned by delays in the year 2003. Strong competition seems to have taken place with JetBlue in 2002. American Airlines is the major airline Southwest is avoiding the most. These are some of the results the model can give.

However, the model is not perfect and several areas remain to be explored. The first path to explore are the unexpected results the model sometimes gives. Changes could be made to improve the model’s quality or some important strategy decisions may turn up. The second path would be introducing a dynamic
variable to model the entry decision, based on what competitors are doing and pricing policies. This would be both very revealing and challenging.

The final word would come to the quality of the model. Regardless of the direction this projects turns to, improving the quality of the static description or starting a new dynamic model, it is necessary to guarantee the robustness of the model before making any forecasts or explaining serious strategy decisions.
A U.S. air traffic hubs

Figure 28: U.S. air traffic hubs in 2008 [16].

The classification of a hub airport is made according to its percentage of the total annual domestic passenger boardings, and enables the separation of U.S. hub airports into three categories: Large Hub: 1% or more; Medium Hub: between 0.25% and 1%; Small Hub: between 0.05% and 0.25%. [17]
B Competitors of Southwest

This section provides information about competitors of Southwest. The Figures 29, 30, 31 and 32 show the route network of Airtran Airways, Frontier Airlines, JetBlue Airways and Alaska Airlines. The tables summarized as Table 33 give an overview of the fleet and the hub structure of the Major carriers. The distinction between a hub city and a focus city can be made the following way: A focus city does not have the importance (e.g. regarding the offered destinations) of a hub. But from a focus city an airline has flights to destinations other than only to its hubs. For example, Northwest Airlines offers from its focus city IND flights to its hubs in MEM, DTW and MSP, but additional flights go, inter alia, to SFO and LAX, which are neither hubs nor focus cities for Northwest Airlines [28]. Regarding Southwest, this definition of hub and focus city does not hold. Southwest does not operate hubs [2], and therefore the definition of a focus city is slightly different. In the case of Southwest, a focus city means a concentration of operations, as described in the Introduction.
Figure 29: Route map from AirTran. The routes given in red show the nonstop connections out of their hub in ATL, the routes in blue show connections from other hubs. AirTran Airways operates further hubs in MCo and BWI [38].
Figure 30: Route map of Frontier. The routes shown in green are routes operated by Frontier Airlines; routes shown in red are operated by its partner airline Lynx Aviation; routes in blue are operated by either Frontier or Lynx Aviation [39].
Figure 31: Route map of JetBlue Airways [40].
Figure 32: Route map of Alaska Airlines. Routes shown in blue are operated by Alaska Airlines, routes shown in brown by its partner airline Horizon Air [41].
### American Airlines (AA)

<table>
<thead>
<tr>
<th>Fleet</th>
<th>Hubs</th>
</tr>
</thead>
<tbody>
<tr>
<td>47 Boeing 777-200ER</td>
<td>Long Haul</td>
</tr>
<tr>
<td>57 Boeing 767-300ER</td>
<td>Long Haul</td>
</tr>
<tr>
<td>15 Boeing 767-200ER</td>
<td>Medium-/Long Haul</td>
</tr>
<tr>
<td>124 Boeing 757-200</td>
<td>Medium-/Long Haul</td>
</tr>
<tr>
<td>28 Airbus A300-600R</td>
<td>Short-/Medium Haul</td>
</tr>
<tr>
<td>77 Boeing 737-800</td>
<td>Short-/Medium Haul</td>
</tr>
<tr>
<td>283 MD-82/83</td>
<td>Short-/Medium Haul</td>
</tr>
</tbody>
</table>

### Continental Airlines (CO)

<table>
<thead>
<tr>
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<th>Hubs</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Boeing 777-200ER</td>
<td>Long Haul</td>
</tr>
<tr>
<td>16 Boeing 767-400ER</td>
<td>Long Haul</td>
</tr>
<tr>
<td>10 Boeing 767-200ER</td>
<td>Medium-/Long Haul</td>
</tr>
<tr>
<td>58 Boeing 757-2/300</td>
<td>Medium-/Long Haul</td>
</tr>
<tr>
<td>27 Boeing 737-900ER</td>
<td>Medium-/Long Haul</td>
</tr>
<tr>
<td>237 Boeing 737-3/5/7/8/900</td>
<td>Short-/Medium Haul</td>
</tr>
</tbody>
</table>

### Delta Air Lines (DL)

<table>
<thead>
<tr>
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<th>Hubs</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Boeing 777-200ER/LR</td>
<td>Long Haul</td>
</tr>
<tr>
<td>21 Boeing 767-400ER</td>
<td>Medium-/Long Haul</td>
</tr>
<tr>
<td>76 Boeing 767-3/300ER</td>
<td>Medium-/Long-Haul</td>
</tr>
<tr>
<td>132 Boeing 757-200</td>
<td>Medium-/Long Haul</td>
</tr>
<tr>
<td>75 Boeing 737-7/800</td>
<td>Short-/Medium Haul</td>
</tr>
<tr>
<td>130 MD-88/90</td>
<td>Short-/Medium Haul</td>
</tr>
</tbody>
</table>
### Northwest Airlines (NW)

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</thead>
<tbody>
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<td>16</td>
<td>Boeing 747-400</td>
<td>Long Haul</td>
</tr>
<tr>
<td>33</td>
<td>Airbus A330-2/300</td>
<td>Medium-/ Long Haul</td>
</tr>
<tr>
<td>71</td>
<td>Boeing 757-2/300</td>
<td>Medium-/ Long Haul</td>
</tr>
<tr>
<td>73</td>
<td>Airbus A320-200</td>
<td>Short-/ Medium Haul</td>
</tr>
<tr>
<td>57</td>
<td>Airbus A319-100</td>
<td>Short-/ Medium Haul</td>
</tr>
<tr>
<td>79</td>
<td>DC 9-30/40/50</td>
<td>Short Haul</td>
</tr>
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</table>

### United Airlines (UA)

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<th>Hubs</th>
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</thead>
<tbody>
<tr>
<td>27</td>
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<tr>
<td>52</td>
<td>Boeing 777-2/200ER</td>
<td>Long Haul</td>
</tr>
<tr>
<td>35</td>
<td>Boeing 767-3/300ER</td>
<td>Medium-/ Long Haul</td>
</tr>
<tr>
<td>37</td>
<td>Boeing 757-200</td>
<td>Medium Haul</td>
</tr>
<tr>
<td>59</td>
<td>Boeing 737-3/500</td>
<td>Short-/ Medium Haul</td>
</tr>
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<td>97</td>
<td>Airbus A320-200</td>
<td>Short-/ Medium Haul</td>
</tr>
<tr>
<td>55</td>
<td>Airbus A319-100</td>
<td>Short-/ Medium Haul</td>
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### US Airways (US)

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<th>Type</th>
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</thead>
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<tr>
<td>9</td>
<td>Airbus A330-300</td>
<td>Long Haul</td>
</tr>
<tr>
<td>9</td>
<td>Boeing 767-200ER</td>
<td>Long Haul</td>
</tr>
<tr>
<td>41</td>
<td>Boeing 757-200</td>
<td>Medium-/ Long Haul</td>
</tr>
<tr>
<td>78</td>
<td>Boeing 737-3/400</td>
<td>Short-/ Medium Haul</td>
</tr>
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<td>31</td>
<td>Airbus A321-200</td>
<td>Short-/ Medium Haul</td>
</tr>
<tr>
<td>75</td>
<td>Airbus A320-200</td>
<td>Short-/ Medium Haul</td>
</tr>
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<td>93</td>
<td>Airbus A319-100</td>
<td>Short-/ Medium Haul</td>
</tr>
<tr>
<td>24</td>
<td>Embraer 190</td>
<td>Short Haul</td>
</tr>
</tbody>
</table>

Table 33: These six tables give information about fleet, fleet assignment and hubs of the U.S. Major carriers. The first two columns give the number of aircraft types in the fleet, the third column the assignment of the aircraft type and the last column the hubs and focus cities (*). For the model hubs and focus cities are not taken from these information. It is done mathematically by computing passenger ratios for each airport [28].
Appendix

C Definition of GDP data

The following excerpts are definitions of the economic sectors included in the supersectors “Professional and Business Service” and “Leisure and hospitality”, whose GDP-data were used in the model. The excerpts are taken from U.S. Department of Labour [44] and refer to definitions given by the North American Industry classification system. They shall give an explanation about the working sectors they include.

Professional, Scientific, and Technical Services sector: “The Professional, Scientific, and Technical Services sector comprises establishments that specialize in performing professional, scientific, and technical activities for others. These activities require a high degree of expertise and training. The establishments in this sector specialize according to expertise and provide these services to clients in a variety of industries and, in some cases, to households. Activities performed include: legal advice and representation; accounting, bookkeeping, and payroll services; architectural, engineering, and specialized design services; computer services; consulting services; research services; advertising services; photographic services; translation and interpretation services; veterinary services; and other professional, scientific, and technical services.”

Management of Companies and Enterprises sector: “The Management of Companies and Enterprises sector comprises (1) establishments that hold the securities of (or other equity interests in) companies and enterprises for the purpose of owning a controlling interest or influencing management decisions or (2) establishments (except government establishments) that administer, oversee,
and manage establishments of the company or enterprise and that normally undertake the strategic or organizational planning and decision making role of the company or enterprise. Establishments that administer, oversee, and manage may hold the securities of the company or enterprise. Establishments in this sector perform essential activities that are often undertaken, in-house, by establishments in many sectors of the economy. By consolidating the performance of these activities of the enterprise at one establishment, economies of scale are achieved.”

**Administrative and Support and Waste Management and Remediation Services sector:** “The Administrative and Support and Waste Management and Remediation Services sector comprises establishments performing routine support activities for the day-to-day operations of other organizations. These essential activities are often undertaken in-house by establishments in many sectors of the economy. The establishments in this sector specialize in one or more of these support activities and provide these services to clients in a variety of industries and, in some cases, to households. Activities performed include: office administration, hiring and placing of personnel, document preparation and similar clerical services, solicitation, collection, security and surveillance services, cleaning, and waste disposal services.”

**Arts, Entertainment, and Recreation sector:** “The Arts, Entertainment, and Recreation sector includes a wide range of establishments that operate facilities or provide services to meet varied cultural, entertainment, and recreational interests of their patrons. This sector comprises (1) establishments that are
involved in producing, promoting, or participating in live performances, events, or exhibits intended for public viewing; (2) establishments that preserve and exhibit objects and sites of historical, cultural, or educational interest; and (3) establishments that operate facilities or provide services that enable patrons to participate in recreational activities or pursue amusement, hobby, and leisure-time interests. Some establishments that provide cultural, entertainment, or recreational facilities and services are classified in other sectors.”

**Accommodation and Food Services sector:** “The Accommodation and Food Services sector comprises establishments providing customers with lodging and/or preparing meals, snacks, and beverages for immediate consumption. The sector includes both accommodation and food services establishments because the two activities are often combined at the same establishment.”

**D Metropolitan and micropolitan Statistical Areas**

This section gives an overview about assumptions made on treatment of the MSA-/mSA- and population-data given by the *U.S. Census Bureau* [37] and the *U.S. Bureau of Economic Analysis (BEA)* [42]. Assumptions regarding the treatment of the MSAs in terms of averaging and aggregating certain data have been made as follows: According to the timetable information of Southwest [2], some airports, even being located in a separate MSA, are counted as part of a bigger MSA that is in close proximity. For example, PVD is located in the Providence-New Bedford-Fall River (MSA). On Southwest’s website [2] though, this airport is referred to as being part of the “Boston Area”. Therefore, the
social and economic influence of the Boston-Cambridge-Quincy (MSA) must also be taken into account, and the data on population and GDP of both MSAs is aggregated.

- SJC with San Jose-Sunnyvale-Santa Clara (MSA) to San Francisco-Oakland-Fremont (MSA)
- PVD with Providence-New Bedford-Fall River (MSA) and MHT with Manchester-Nashua (MSA) to Boston-Cambridge-Quincy (MSA)
- BWI with Baltimore-Towson (MSA) to Washington-Arlington-Alexandria (MSA)
- ONT with Riverside-San Bernardino-Ontario (MSA) to Los Angeles-Long Beach-Santa Ana (MSA)

Independent from the allocation in Southwest’s booking system, these airports serve the following MSAs according to their assignment of the U.S. Office of Management and Business (OMB) [37]:

- BUR to Los Angeles-Long Beach-Santa Ana (MSA)
- PBI to Miami-Ft. Lauderdale-Pompano Beach (MSA)

The data on population and GDP of the MSAs Odessa, TX and Midland, TX have been aggregated, because the airport in this region, Odessa/Midland International Airport (MAF) serves both cities.
Figure 33: MSAs and mSAs 2007. This map shows the Metro (MSAs)- and micropolitan areas (mSAs) of the U.S. for the year 2007. The dark green shadowed areas mark the MSAs, the light-colored areas the mSAs.
<table>
<thead>
<tr>
<th>Code</th>
<th>City / City Region</th>
<th>MSA/ mSA</th>
<th>Pop.</th>
<th>GDP Total</th>
<th>GDP Leisure</th>
<th>GDP Prof.</th>
</tr>
</thead>
<tbody>
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<td>MSA</td>
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<td>253601</td>
<td>690</td>
<td>3162</td>
</tr>
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<td>MSA</td>
<td>840871</td>
<td>319300</td>
<td>894</td>
<td>3995</td>
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<td>MSA</td>
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<td>28967</td>
<td>932</td>
<td>4114</td>
</tr>
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<td>24556</td>
<td>727</td>
<td>2669</td>
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<td>MSA</td>
<td>127264</td>
<td>3436</td>
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<td>MSA</td>
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<td>7160</td>
<td>243</td>
<td>1451</td>
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<td>MSA</td>
<td>342380</td>
<td>18977</td>
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<td>1451</td>
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<td>AHN</td>
<td>Athens-Clarke County, GA</td>
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<td>175</td>
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<td>ATL</td>
<td>Atlanta-Sandy Springs-Marietta, GA</td>
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<td>4770111</td>
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<td>Kahului-Wailuku, HI</td>
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<td>mSA</td>
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<td>106568</td>
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<td>MTT</td>
<td>Montrose, CO</td>
<td>mSA</td>
<td>36377</td>
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<td>EWN</td>
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<td>Canon City, CO</td>
<td>mSA</td>
<td>47507</td>
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</tbody>
</table>
Table 34: MSAs and mSAs and airports [37] [42].

<table>
<thead>
<tr>
<th>Code</th>
<th>City Region</th>
<th>MSA</th>
<th>Pop.</th>
<th>GDP Total</th>
<th>GDP Leisure</th>
<th>GDP Prof.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISN</td>
<td>Williston, ND</td>
<td>mSA</td>
<td>19375</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The first column gives the code of an airport, the second column the respective MSA or mSA. Entries marked with (*) mean that Statistical Areas are aggregated, as described in the introduction of this Appendix. The fourth column gives the population of the areas, the last three columns give information about the GDP in millions of US Dollars. The values of Population and GDP are the geometric means of the data for 2001 to 2006 [37] [42].
E EViews source code

' Updated on 19th January by Jon
' Code rewritten to keep track of possible dummy variables included
' in the data but excluded from the modelling. The number of
' variables imported has to be explicitized, same goes for the
' number of variables excluded. Changed the plotted coefficients.
' Now not the betas but the marginal effects for probit.
*********************************************************************

' The next line creates a workfile, necessary to start working.
wfcreeate u 27966

' Declaration of variables
scalar nbimp 'number of variables imported.
' Has to be updated with new variables.
' Currently, there are fifty-nine
' variables
' in the model.
scalar nbvar 'number of variables in the model.
' INCLUDING constant.
scalar nb_case 'number of cells in the matrix for one
' quarter
scalar length 'length of the matrix = number of rows
scalar excluded 'number of variables excluded in the 
'regression.

nbimp = 77

nb_case = 7

length = nb_case*6*4

excluded = 39

'Variables excluded are : pax_nb, reg15, paxhub1, 
'wright slot aa_paxhub1 aa_paxhub2 aa_paxhub3 aa_paxhub4 us_paxhub1 
'us_paxhub2 us_paxhub3 us_paxhub4 ua_paxhub1 ua_paxhub2 ua_paxhub3 
'ua_paxhub4 nw_paxhub1 nw_paxhub2 nw_paxhub3 nw_paxhub4 dl_paxhub1 
'dl_paxhub2 dl_paxhub3 dl_paxhub4 co_paxhub1 co_paxhub2 co_paxhub3 
'co_paxhub4 hub150 route50 route100 endpoint50 endpoint100 n_ 
'dep_delay arr_delay dist_ratio ops

'the order beneath is to compute number of variables in the regression:

'nbvar = nbimp + quadratic terms - year&quarter + dist<=200 - excluded 
'veariables

'nbvar = nbimp + 3 - 2 + 1 - excluded

'We create a matrix to store all the regression results

matrix(length,nbvar) results

'This next step opens the data files, then runs the regression 
'and finally stores the result in the matrix.
for !i = 7 to 7

for !j = 4 to 4

'Opens the data files. Has to be updated with new
'variables. Dropstrings excludes all cells that
'include letters.

read(t=txt,dropstrings) G:\Southwest\data_7\WN_actual_routes_200!i_!j_.txt year quarter pax_nb
dist carrier_nb population leisure_ind business_ind
reg1 reg2 reg3 reg4 reg5 reg6 reg7 reg8 reg9 reg10
reg11 reg12 reg13 reg14 reg15 paxhub1 paxhub2 paxhub3
paxhub4 wright slot aa_paxhub1 aa_paxhub2 aa_paxhub3
aa_paxhub4 us_paxhub1 us_paxhub2 us_paxhub3 us_paxhub4
ua_paxhub1 ua_paxhub2 ua_paxhub3 ua_paxhub4 nw_paxhub1
nw_paxhub2 nw_paxhub3 nw_paxhub4 dl_paxhub1 dl_paxhub2
dl_paxhub3 dl_paxhub4 co_paxhub1 co_paxhub2 co_paxhub3
co_paxhub4 hub50 hub100 hub150 route50 route100 endpoint50
endpoint100 n_ aa_hub us_hub ua_hub nw_hub dl_hub co_hub
dep_delay arr_delay max_delay dist_ratio jetblue airtran
frontier alaska ops wn_presence
'77 variables imported
'Before scaling of dist, is test if distance is shorter
' than 200km
series dist_t = dist<=200

' In this part, we create the series containing the
' variables and scale them.

dist = dist/1000
population = population/1000000

'Trick to compute number of competitors, nb of competitors =
'total carriers - southwest’s presence

series competitor_nb
competitor_nb = (carrier_nb - wn_presence)

'Series with the number 2 on the end are used for
' quadratic terms.

series dist2 = dist^2
series population2 = population^2
series competitor_nb2 = competitor_nb^2
'Series that corrects the endpoints by excluding hubs
endpoint50 = endpoint50 - hub50
endpoint100 = endpoint100 - hub100

'Auxiliary regressions
equation eq_aux1.ls competitor_nb c population
series comp_star = resid
series comp_star2_temp = comp_star^2

equation eq_aux2.ls comp_star2_temp c population population2
series comp_star2 = resid

'Models have to be updated with new variables
equation eq_probit.binary(d=n,q,h) wn_presence c dist dist2
population population2 comp_star comp_star2 leisure_ind
business_ind reg1 reg2 reg3 reg4 reg5 reg6 reg7 reg8 reg9
reg10 reg11 reg12 reg13 reg14 paxhub2 paxhub3 paxhub4 aa_hub
us_hub ua_hub nw_hub dl_hub co_hub dist_t hub50 hub100
max_delay jetblue airtran frontier alaska

'40 variables in the model,
'including constant, wn_presence is omitted as it is not a variable
equation eq_logit.binary(d=1,q,h) wn_presence c dist dist2  
population population2 comp_star comp_star2 leisure_ind  
business_ind reg1 reg2 reg3 reg4 reg5 reg6 reg7 reg8 reg9  
reg10 reg11 reg12 reg13 reg14 paxhub2 paxhub3 paxhub4 aa_hub  
us_hub ua_hub nw_hub dl_hub co_hub dist_t hub50 hub100 max_delay  
jetblue airtran frontier alaska  
'Test for endogeneity. Has to be updated with variables in the model.  
vector(nbvar-1) r2_results  
equation eq01.ls dist c wn_presence  
equation eq02.ls dist2 c wn_presence  
equation eq03.ls population c wn Presence  
equation eq04.ls population2 c wn_presence  
equation eq05.ls comp_star c wn_presence  
equation eq06.ls comp_star2 c wn_presence  
equation eq07.ls leisure_ind c wn_presence  
equation eq08.ls business_ind c wn_presence  
equation eq09.ls reg1 c wn_presence  
equation eq10.ls reg2 c wn_presence  
equation eq11.ls reg3 c wn_presence  
equation eq12.ls reg4 c wn_presence
equation eq13.ls reg5 c wn_presence
equation eq14.ls reg6 c wn_presence
equation eq15.ls reg7 c wn_presence
equation eq16.ls reg8 c wn_presence
equation eq17.ls reg9 c wn_presence
equation eq18.ls reg10 c wn_presence
equation eq19.ls reg11 c wn_presence
equation eq20.ls reg12 c wn_presence
equation eq21.ls reg13 c wn_presence
equation eq22.ls reg14 c wn_presence

equation eq23.ls paxhub2 c wn_presence
equation eq24.ls paxhub3 c wn_presence
equation eq25.ls paxhub4 c wn_presence

equation eq26.ls aa_hub c wn_presence
equation eq27.ls us_hub c wn_presence
equation eq28.ls ua_hub c wn_presence
equation eq29.ls nw_hub c wn_presence
equation eq30.ls dl_hub c wn_presence
equation eq31.ls co_hub c wn_presence

equation eq32.ls dist_t c wn_presence
equation eq33.ls hub50 c wn_presence
equation eq34.ls hub100 c wn_presence

equation eq35.ls max_delay c wn_presence

equation eq36.ls jetblue c wn_presence
equation eq37.ls airtran c wn_presence
equation eq38.ls frontier c wn_presence
equation eq39.ls alaska c wn_presence

'We store the r2 of each equation in the vector r2_results
for !k = 1 to nbvar-1
  if !k<10 then r2_results(!k) = eq0!k.@r2
  else r2_results(!k) = eq!k.@r2
endif
next

'Declaration of the regression results. They are stored in a
'list of coefficients.

coef beta_probit = eq_probit.@coefs
coef beta_logit = eq_logit.@coefs
coef se_probit = eq_probit.@stderrs
coef signif_probit = eq_probit.@tstats

'Getting probabilities instead of tstats.
coef(nbvar-1) probs
for !k = 2 to nbvar
probs(!k-1) = 2*(1 - @cnorm(@abs(signif_probit(!k))))
next

'Compute the mean of each series. Needed to compute derivatives
'on logit and probit. Has to be updated with new variables with
'same order as regression.
vector(nbvar) mean_values
mean_values(1) = @mean(c)
mean_values(2) = @mean(dist)
mean_values(3) = @mean(dist2)
mean_values(4) = @mean(population)
mean_values(5) = @mean(population2)
mean_values(6) = @mean(comp_star)
mean_values(7) = @mean(comp_star2)
mean_values(8) = @mean(leisure_ind)
mean_values(9) = @mean(business_ind)
mean_values(10) = @mean(reg1)
mean_values(11) = @mean(reg2)
mean_values(12) = @mean(reg3)
mean_values(13) = @mean(reg4)
mean_values(14) = @mean(reg5)
mean_values(15) = @mean(reg6)
mean_values(16) = @mean(reg7)
mean_values(17) = @mean(reg8)
mean_values(18) = @mean(reg9)
mean_values(19) = @mean(reg10)
mean_values(20) = @mean(reg11)
mean_values(21) = @mean(reg12)
mean_values(22) = @mean(reg13)
mean_values(23) = @mean(reg14)

mean_values(24) = @mean(paxhub2)
mean_values(25) = @mean(paxhub3)
mean_values(26) = @mean(paxhub4)
mean_values(27) = @mean(aa_hub)
mean_values(28) = @mean(us_hub)
mean_values(29) = @mean(ua_hub)
mean_values(30) = @mean(nw_hub)
mean_values(31) = @mean(dl_hub)
mean_values(32) = @mean(co_hub)

mean_values(33) = @mean(dist_t)
mean_values(34) = @mean(hub50)
mean_values(35) = @mean(hub100)

mean_values(36) = @mean(max_delay)

mean_values(37) = @mean(jetblue)
mean_values(38) = @mean(airtran)
mean_values(39) = @mean(frontier)
mean_values(40) = @mean(alaska)

'This next loop is used to place the regression results in the matrix.

for !k = 2 to nbvar

results(4*nb_case*(!i-2) + nb_case*(!j-1) + 1,!k-1) = beta_probit(!k)

results(4*nb_case*(!i-2) + nb_case*(!j-1) + 2,!k-1) = se_probit(!k)

results(4*nb_case*(!i-2) + nb_case*(!j-1) + 3,!k-1) = probs(!k-1)

results(4*nb_case*(!i-2) + nb_case*(!j-1) + 4,!k-1) = @cnorm((@transpose(mean_values)*beta_probit)(1))
*beta_probit(!k)

results(4*nb_case*(!i-2) + nb_case*(!j-1) + 5,!k-1)
 = @clogistic((@transpose(mean_values)*beta_logit)(1))
*(1-@clogistic((@transpose(mean_values)*beta_logit)(1)))
*beta_probit(!k)

results(4*nb_case*(!i-2) + nb_case*(!j-1) + 6,!k-1)
 = @exp((@transpose(mean_values)*beta_logit)(1))
*@exp(beta_logit(!k))

results(4*nb_case*(!i-2) + nb_case*(!j-1) + 7,!k-1)
 = r2_results(!k-1)
next

results(4*nb_case*(!i-2) + nb_case*(!j-1) + 1,nbvar)
 = eq_probit.@r2

results(4*nb_case*(!i-2) + nb_case*(!j-1) + 2,nbvar)
 = @exp((@transpose(mean_values)*beta_logit)(1))

'Ploting a desired variable
'The following loop allows to create a matrix that
contains all the regression coefficients in easy-to-use form for plotting.

matrix(24,nbvar-1) coeff_plot

for !k = 2 to nbvar
coeff_plot(4*(!i-2) + !j,!k-1)
  = @cnorm((@transpose(mean_values)
*beta_probit)(1))*beta_probit(!k)
next

next

next

*************************************************************************

At this stage, the matrix with all the regression results is created. The
next step is to create the Excel file which will contain all these numbers.
To do this, you first have to convert the matrix into a group. This is done
with the mtos command. Adding the sample size is a trick to make the
size of the matrix and the group match.

sample s_export 1 168 '168 = nb_case*6*4
mtos(results, export_results, s_export)
'Declaration of a series containing letters. Eviews calls it an 'alpha series. This code adds a column containing 200X:QY.

alpha(length) year_quarter

for !i = 2 to 7
for !j = 1 to 4
  year_quarter(4*nb_case*(!i-2) + nb_case*(!j-1) + 1) = "200"+@str(!i)+"Q"+@str(!j)
next
next

'We add 200X:QY in the group just before writing the excel file.
export_results.add year_quarter

write G:\temp\results_model9.xls export_results

'In this next step, we clear some of the objects in the workfile that 'are not really needed.

for !k = 1 to nbvar-1
if \( k < 10 \) then delete ser0!k eq0!k

else delete ser!k eq!k

endif

next
F  Python source code

Figure 34: Python Flowchart
# entry_model_data_parse_by_yq

""

Parse complete_coupon dataset for WN entry model project.

Modified 19 November 2008 for WN and 6 main carriers.
Modified 28 November 2008 with addition of nautical mile distance.
Modified 29 November 2008 with 0-1 routes, c.f. 'all large carrier static network'.
Modified 30 November 2008 with number of carriers on all actual routes.
Modified 3 December 2008 with .txt output of full airport list.
Modified 13 December 2008 with route population (geometric mean of endpoints).
Modified 19 December 2008 with leisure indicator function call.
Modified 19 December 2008 with business indicator function call.
Modified 19 January 2009 with manual CHI, NYC IATA code error traps (to change).
Modified 20 January 2009 with automatic passenger filter.

""

import cPickle,time,os,sys
module_dir=os.path.join('Project','code')
sys.path.insert(0,module_dir)

from airport_location_function_modified_return import *
from safe_cPickle import *
from scipy import *
from route_population_geom_mean_function import *
from route_leisure_function import leisure_function
from route_business_function import business_function

data_path='C:/Project/data/'; filename='complete_coupon'

passenger_filter_flag=True

#year_list=[2007]; quarter_list=[4]

leisure_dict=leisure_function(0.05)
business_dict=business_function(0.10)

t01=time.time(); print; print 'Loading dictionary: '+filename
c_x_x=open(data_path+filename,'r'); dt=cPickle.load(c_x_x)
print str(time.time()-t01)+' seconds to load dictionary.'
c_x_x.close()
# the following CHI-removal (from complete_coupon) error trap is not generic
aa=dt['Origin'].index('CHI')
for jj in dt.keys(): dt[jj].pop(aa)

# the following NYC-removal (from complete_coupon) error trap is not generic
aa=dt['Origin'].index('NYC')
for jj in dt.keys(): dt[jj].pop(aa)

r_sphere=6372.7974775959065 # km converted to miles and nautical miles below
carrier='WN'; print; print 'Carrier '+carrier

def distance_calculator(dest_coords_degrees,origin_coords_degrees):

dest_coords_radians=[[pi/180)*dest_coords_degrees[0],
                      (pi/180)*dest_coords_degrees[1]]
origin_coords_radians=[[pi/180)*origin_coords_degrees[0],
                      (pi/180)*origin_coords_degrees[1]]
p1,l1=dest_coords_radians[0],dest_coords_radians[1]
p2,l2=origin_coords_radians[0],origin_coords_radians[1]
l=abs(l1-l2)
num=sqrt(((cos(p2)*sin(l))**2)+(((cos(p1)*sin(p2))-(sin(p1)*cos(p2)*cos(l)))**2))
den=sin(p1)*sin(p2)+cos(p1)*cos(p2)*cos(l)
theta=arctan(num/den)
distance=r_sphere*theta
return distance

t02=time.time(); print; print 'Parsing data: '+filename

full_data_dict={}
for i in year_list:
    for j in quarter_list:
        key=str(i)+'_'+str(j)
        full_data_dict[key]=[]

airport_list_all=[]; competitor_dict_by_route={}
for i in range(381526):

    if (float(i)/3815)==i/3815: print str(i/3815)+'%

try:

    key_i=str(dt['Year'][i])+'_'+str(dt['Quarter'][i])
dest_name=airport_location(dt['Dest'][i])[0]
origin_name=airport_location(dt['Origin'][i])[0]

    if dt['Dest'][i] not in airport_list_all:
        airport_list_all.append(dt['Dest'][i])
    if dt['Origin'][i] not in airport_list_all:
        airport_list_all.append(dt['Origin'][i])
dest_coords_degrees = airport_location(dt['Dest'][i])[1]
origin_coords_degrees = airport_location(dt['Origin'][i])[1]

distance = distance_calculator(dest_coords_degrees, origin_coords_degrees)
distance = abs(distance)
# see distance error trap comment below

route_list = [dt['Dest'][i], dt['Origin'][i]]
route_list.sort()
route_ = route_list[0] + '_-' + route_list[1]

try: competitor_dict_by_route[route_][key_i].append(dt['OpCarrier'][i])
except KeyError:
    try: competitor_dict_by_route[route_][key_i] = [dt['OpCarrier'][i]]
    except KeyError:
        competitor_dict_by_route[route_] = {}
        competitor_dict_by_route[route_][key_i] = [dt['OpCarrier'][i]]

if dt['OpCarrier'][i] == carrier:

    data = [dt['OpCarrier'][i], dt['Origin'][i], origin_name, 
    dt['Dest'][i], dest_name, dt['Origin'][i] + '_' + dt['Dest'][i], 
    ...
try: leisure_route=max(leisure_dict[dt['Origin'][i]],
   leisure_dict[dt['Dest'][i]])
except KeyError:
    try: leisure_route=leisure_dict[dt['Origin'][i]]
    except KeyError:
       try: leisure_route=leisure_dict[dt['Dest'][i]]
       except KeyError: leisure_route=0

try:
    if business_dict[dt['Origin'][i]]==1 and
       business_dict[dt['Dest'][i]]==1:
       business_route=1
    else: business_route=0
except KeyError: business_route=0

data=[dt['OpCarrier'][i],dt['Origin'][i]+'_'+dt['Dest'][i],
      dt['Year'][i],dt['Quarter'][i],int(dt['TotalPass'][i]),
      int(round(distance)),len(competitor_dict_by_route[dt['Origin'][i]+
      '_'+dt['Dest'][i]][key_i]),
      int(round(distance/1.609344)),
      int(round(distance/1.852)),1]
route_population(dt[‘Origin’][i],dt[‘Dest’][i]),
leisure_route,business_route,1]

if passenger_filter_flag:
    if (eval(dt[‘Year’][i]) in year_list) and
    (eval(dt[‘Quarter’][i]) in quarter_list) and
    int(dt[‘TotalPass’][i])>=90:
        full_data_dict[key_i].append(data)

elif not passenger_filter_flag:
    if (eval(dt[‘Year’][i]) in year_list) and
    (eval(dt[‘Quarter’][i]) in quarter_list):
        full_data_dict[key_i].append(data)

except TypeError: continue

print str(time.time()-t02)+' seconds to parse data.'

airport_list_all.sort(); airport_list_out=[]
for ii in airport_list_all: airport_list_out.append([ii,airport_location(ii)[0],
                                                      airport_location(ii)[1]])

path=''

if passenger_filter_flag: f=open(‘all_routes_2002_2007_passfilt.txt’,’w’)
elif not passenger_filter_flag: f=open(‘all_routes_2002_2007.txt’,’w’)
for jj in airport_list_out:
output=str(jj[0])+'\t'+str(jj[1])+'\t'+str(jj[2])+'\n'
f.write(output)
f.close()

if passenger_filter_flag: f=open(data_path+'all_routes_2002_2007_passfilt.txt','w')
elif not passenger_filter_flag: f=open(data_path+'all_routes_2002_2007.txt','w')
for jj in airport_list_out:
    output=str(jj[0])+'\t'+str(jj[1])+'\t'+str(jj[2])+'\n'
f.write(output)
f.close()

t03=time.time(); print; print 'Checking all possible routes.'

actual_route_dict={}  
for i in full_data_dict.keys(): actual_route_dict[i]=[]  
for i in full_data_dict.keys():
    for j in full_data_dict[i]:
        key=j[1]; period_key=j[2]+'_'+j[3]
        if key not in actual_route_dict[period_key]:
            actual_route_dict[period_key].append(key)

route_list_all_possible=[]
for x in airport_list_all:
    for y in airport_list_all:
if x!=y:
    pair_list=[x,y]
    pair_list.sort()
    pair_string=pair_list[0]+'_'+pair_list[1]
    if pair_string not in route_list_all_possible:
        route_list_all_possible.append(pair_string)

print; print 'Airports in full static network '+str(len(airport_list_all))
print 'Total number of possible routes '+str(len(route_list_all_possible)); print

for i in year_list:
    for j in quarter_list:
        key=str(i)+'_'+str(j)
        path=''
        if passenger_filter_flag:
            f=open(data_path+carrier+'_actual_routes_'+key+'_passfilt.txt','w')
        elif not passenger_filter_flag:
            f=open(data_path+carrier+'_actual_routes_'+key+'.txt','w')
        for k in full_data_dict[key]:
            if k[0]==carrier:
                output=''
                for l in k: output=output+str(l)+'	'
                output=output+'
                f.write(output)
            else: pass
output=''
for mm in route_list_all_possible:
    if mm not in actual_route_dict[key]:
        distance_=distance_calculator(airport_location(mm.split('_')[1])[1],
                                         airport_location(mm.split('_')[0])[1])
        distance_=abs(distance_)

        # need trap: some routes return <0 distances, e.g. OGG_SSI

        """
        output=output+carrier+'	'+mm.split('_')[0]+'	'+airport_location(mm.split('_')[0])[0]+'	' + mm.split('_')[1]+'	'+airport_location(mm.split('_')[1])[0]+'
            	'+str(i)+'	'+str(j)+'	'+str(int(round(distance_)))+'	'+str(int(round(distance_/1.609344)))+'	'+str(int(round(distance_/1.852)))+'0'
        """

    try: leisure_route=max(leisure_dict[mm.split('_')[0]],
                      leisure_dict[mm.split('_')[1]])
    except KeyError:
        try: leisure_route=leisure_dict[mm.split('_')[0]]
        except KeyError:
            try: leisure_route=leisure_dict[mm.split('_')[1]]
except KeyError: leisure_route=0

try:
    if business_dict[mm.split('_')[0]]==1 and business_dict[mm.split('_')[1]]==1: business_route=1
else: business_route=0
except KeyError: business_route=0

try:
    output=output+carrier+'	'+mm+'	'+str(i)+'	'+str(j)+'	'+str(int(round(distance_)))+'	'+str(len(competitor_dict_by_route[mm][key]))+'	'+route_population(mm.split('_')[0],mm.split('_')[1])+'	'+str(leisure_route)+'	'+str(business_route)+'
    
except KeyError:
    output=output+carrier+'	'+mm+'	'+str(i)+'	'+str(j)+'	'+str(int(round(distance_)))+'	'+'0'+'	'+str(len(competitor_dict_by_route[mm][key]))+'	'+route_population(mm.split('_')[0],mm.split('_')[1])+'	'+str(leisure_route)+'	'+str(business_route)+'

output=output+'

f.write(output)
f.close()
print 'Year:quarter, total number of actual routes '+str(i)+':'+str(j)+
', ',+str(len(actual_route_dict[key]))

print str(time.time()-t03)+' seconds to complete.'

******************************************************************************

# airport_location_function_modified_return

*****

Airport location degrees / function (2).

Modified 10 November 2008 to return airport name.

*****

import os,sys,pickle

module_dir=os.path.join('Project','code')
sys.path.insert(0,module_dir)

from airport_location_dict_generator import *
data_path='C:/Project/data/
try: f=open(data_path+'airport_locations_degrees_dict','r')
ext except IOError:
    create_location_dict()
    f=open(data_path+'airport_locations_degrees_dict','r')

airport_locations_degrees_dict=pickle.load(f)
f.close()

def airport_location(iata_code):
    try: return [airport_locations_degrees_dict[iata_code][0],
                airport_locations_degrees_dict[iata_code][1]]
    except KeyError:
        print iata_code+' is not a valid code.'
        return

*******************************************************************************
# airport_location_dict_generator

*************

Airport location (degrees) / dictionary generator.
Parses .csv raw data file into Python dictionary.  
Key: IATA code. Value: ['Airport (Country)',[latitude (N/S),longitude (W/E)]].

Note: coordinates in degrees, not radians.

Steve Lawford : 22 July 2008
Modified 19 January 2009 with removal of CHI and NYC IATA city codes.

```python
import os,csv,pickle
def create_location_dict():
    data_path='C:/Project/data/

    f=open(data_path+'airport_locations.csv','r')
    reader=csv.reader(f)

    airport_location_dict={}
    print; print 'Parsing .csv file'; print
    for row in reader:
        if row[0]!='CHI' and row[0]!='NYC':
```
[float(row[5]),float(row[6])])

f.close()

g=open(data_path+'airport_locations_degrees_dict','w')
pickle.dump(airport_location_dict,g)
g.close()

return

*******************************************************************************

# safe_cPickle


Safe cPickle (dump) function.


Call with:

from safe_cPickle import *
safe_cPickle_dump(data_path,filename,object)
def safe_cPickle_dump(data_path, filename, object):

    import sys, cPickle

    try:
        f = open(data_path + filename, 'r'); f.close(); rsp = ''
        while rsp != 'n' and rsp != 'y':
            rsp = raw_input('(safe_cPickle has detected object "' + filename + '\n')
        if rsp == 'y':
            g = open(data_path + filename, 'w'); cPickle.dump(object, g); g.close()
        else:
            sys.exit(0)
    except IOError:
        print '(safe_cPickle has not detected object "' + filename + '\n
    g = open(data_path + filename, 'w')
    cPickle.dump(object, g)
    g.close()

    return

*******************************************************************************

# route_population_geom_mean_function
Appendix

Socio-demographic data parse (from .xls)
- for WN entry model project.

Modified 13 December 2008 for population calculation and function return.

```
import cPickle,time
from safe_cPickle import *
from scipy import *

def route_population(end1,end2):

    data_path='C:/Project/data/
    try:
        c_x_x=open(data_path+'airport_populations','r')
        airport_dict=cPickle.load(c_x_x)
        c_x_x.close()
    except IOError:
        f=open(data_path+'population_by_us_airport.txt','r')
        airport_dict={}
```
for i in f:
    j=i.split(’\t’)
    if j[0] not in airport_dict.keys():
        airport_dict[j[0]]=j[3].split(’\n’)[0]
        print j
f.close()
safe_cPickle_dump(data_path,’airport_populations’,airport_dict)
ends=[end1,end2]
ends.sort()

try: return str(int(sqrt(float(airport_dict[ends[0]])*
                        float(airport_dict[ends[1]]))))
except KeyError:
    print ’Error: endpoint not in dictionary.’
sys.exit(0)

*******************************************************************************

# route_leisure_function

"""

Socio-demographic data parse (from .xls) / leisure route indicator.  
- for WN entry model project.
import cPickle
from safe_cPickle import *
from scipy import *

def leisure_function(leisure_threshold):

    data_path='C:/Project/data/
    try:
        c_x_x=open(data_path+'airport_leisure','r')
        airport_leisure_dict=cPickle.load(c_x_x)
        c_x_x.close()
    except IOError:
        f=open(data_path+'gdp_msa_by_us_airport.txt','r')
        airport_leisure_dict={}
        for i in f:
            j=i.split('	')
            if j[0] not in airport_leisure_dict.keys() and j[2]!='' and
            j[3]!='':
                airport_leisure_dict[j[0]]=[j[1],float(j[3])/float(j[2])]
airport_leisure_sort_list=[]

ak=airport_leisure_dict.keys(); aksort=[]

for i in range(len(ak)):
    airport_leisure_sort_list.append(str(airport_leisure_dict
    [ak[i]][1])+'_'+ak[i])

    aksort.append(airport_leisure_dict[ak[i]][1])

aksort.sort()

akrsort=[]

for i in range(len(aksort)-1,0,-1):
    akrsort.append(aksort[i])

leisure_list=[]

for j in akrsort:
    for k in range(len(airport_leisure_sort_list)):
        if str(j)==airport_leisure_sort_list[k].split('_')[0]:
            leisure_list.append([airport_leisure_sort_list[k].split
            ('_')[1],airport_leisure_dict[airport_leisure_sort_list
            [k].split('"')[1]][0],airport_leisure_dict
            [airport_leisure_sort_list[k].split('"')[1]][1]])

            airport_leisure_sort_list.pop(k)

            break

print

for i in leisure_list: print i
print

indicator_dict={}
for i in leisure_list:
    if i[2]>=leisure_threshold: indicator_dict[i[0]]=1
    else: indicator_dict[i[0]]=0

return indicator_dict

*******************************************************************************

# route_business_function

""

Socio-demographic data parse (from .xls) / business route indicator.
- for WN entry model project.


""

import cPickle
from safe_cPickle import *
from scipy import *
def business_function(business_threshold):

data_path='C:/Project/data/'
try:
    c_x_x=open(data_path+'airport_business','r')
    airport_business_dict=cPickle.load(c_x_x)
    c_x_x.close()
except IOError:
    f=open(data_path+'gdp_msa_by_us_airport.txt','r')
    airport_business_dict={}
    for i in f:
        j=i.split('	')
        if j[0] not in airport_business_dict.keys() and j[2]!='' and
            j[4]!='' and j[4]!='
            airport_business_dict[j[0]]=j[1],
            float(j[4].split('\n')[-1])/float(j[2])

airport_business_sort_list=[]
ak=airport_business_dict.keys()[::-1]; aksort=[]
for i in range(len(ak)):
    airport_business_sort_list.append(str(airport_business_dict[ak[i]])[1]+ak[i])
    aksort.append(airport_business_dict[ak[i]][1])
```python
aksort.sort()

akrsort=[]
for i in range(len(aksort)-1,0,-1):
    akrsort.append(aksort[i])

business_list=[]
for j in akrsort:
    for k in range(len(airport_business_sort_list)):
        if str(j)==airport_business_sort_list[k].split('_')[0]:
            business_list.append([airport_business_sort_list[k].split('_')[1],airport_business_dict[airport_business_sort_list[k].split('_')[1]]][0],airport_business_dict[airport_business_sort_list[k].split('_')[1]]][1])
            airport_business_sort_list.pop(k)
            break

print
for i in business_list: print i
print

indicator_dict={}  
for i in business_list:
    if i[2]>=business_threshold: indicator_dict[i[0]]=1
    else: indicator_dict[i[0]]=0
```
return indicator_dict

*******************************************************************************

# entry_model_hub_detection

"""

Hub detection based on complete_coupon for WN entry model project.

Steve Lawford: 3 January 2009.
Modified 12 January 2009 with text file output.
Modified 20 January 2009 with automatic passenger filter.
Modified 21 January 2009 with carrier loop.

"""

import cPickle, time, os, sys
from airport_location_function_ import *

module_dir=os.path.join('Project','code')
sys.path.insert(0,module_dir)
from safe_cPickle import *
from scipy import *

data_path='C:/Project/data/'; filename='complete_coupon'

passenger_filter_flag=True

t01=time.time(); print; print 'Loading dictionary: '+filename

c_x_x=open(data_path+filename,'r'); dt=cPickle.load(c_x_x)
print str(time.time()-t01)+' seconds to load dictionary.'
c_x_x.close()

year=['2002','2003','2004','2005','2006','2007']; quarter=['1','2','3','4']
#year=['2007']; quarter=['4']

full_airports=[]
for i in range(len(dt['OpCarrier'])):
    if dt['Dest'][i] not in full_airports:
        full_airports.append(dt['Dest'][i])
    if dt['Origin'][i] not in full_airports:
        full_airports.append(dt['Origin'][i])

full_airports.pop(full_airports.index('NYC'))
full_airports.pop(full_airports.index('CHI'))
close_dict_0_50={}
for i in full_airports: close_dict_0_50[i]=[]
close_dict_50_100={}
for i in full_airports: close_dict_50_100[i]=[]
close_dict_100_150={}
for i in full_airports: close_dict_100_150[i]=[]

r=6372.7974775959065
print 'Creating nearby airport dictionaries.'
for i in full_airports:
    for j in full_airports:
        if i!=j:
            p1,l1=(pi/180)*airport_location(i)[0],(pi/180)*
            airport_location(i)[1]
p2,l2=(pi/180)*airport_location(j)[0],(pi/180)*
            airport_location(j)[1]
l=abs(l1-l2)
num=sqrt(((cos(p2)*sin(l))**2)+(((cos(p1)*sin(p2))-\
    (sin(p1)*cos(p2)*cos(l)))**2))
den=sin(p1)*sin(p2)+cos(p1)*cos(p2)*cos(l)
theta=arctan(num/den)
distance=abs(int(round(r*theta)))
if distance<=50: close_dict_0_50[i].append(j)
if distance>50 and distance<=100: close_dict_50_100[i].append(j)
if distance>100 and distance<=150: close_dict_100_150[i].append(j)
print 'Nearby airport dictionaries complete.'

safe_cPickle_dump(data_path,'close_dict_0_50',close_dict_0_50)
safe_cPickle_dump(data_path,'close_dict_50_100',close_dict_50_100)
safe_cPickle_dump(data_path,'close_dict_100_150',close_dict_100_150)

for carrier in ['WN','AA','CO','DL','NW','UA','US']:
    for year_ in year:
        for quarter_ in quarter:
            print year_; print quarter_; print
            carrier_airports=[]; print
            print 'Compiling carrier airport list: '+carrier; print
            for i in range(len(dt['OpCarrier'])):
                if passenger_filter_flag:
                    if dt['OpCarrier'][i]==carrier and dt['Year'][i]==year_ and dt['Quarter'][i]==quarter_ and int(dt['TotalPass'][i])>=90:
                        if dt['Dest'][i] not in carrier_airports:
                            carrier_airports.append(dt['Dest'][i])
                        if dt['Origin'][i] not in carrier_airports:
                            carrier_airports.append(dt['Origin'][i])
                elif not passenger_filter_flag:
                    if dt['OpCarrier'][i]==carrier and dt['Year'][i]==year_ and dt['Quarter'][i]==quarter_:
                        if dt['Dest'][i] not in carrier_airports:
                            carrier_airports.append(dt['Dest'][i])
                        if dt['Origin'][i] not in carrier_airports:
                            carrier_airports.append(dt['Origin'][i])
carrier_airports.append(dt['Dest'][i])
if dt['Origin'][i] not in carrier_airports:
carrier_airports.append(dt['Origin'][i])

print carrier_airports; print

carrier_dict={}
for i in carrier_airports: carrier_dict[i]=[0,0,0,0,0,0]

for i in range(len(dt['OpCarrier'])):
    if passenger_filter_flag:
        if dt['Year'][i]==year_ and dt['Quarter'][i]==quarter_ and int(dt['TotalPass'][i])>=90:
            if dt['Origin'][i] in carrier_dict.keys():
                carrier_dict[dt['Origin'][i]][1]+=dt['TotalPass'][i]
                carrier_dict[dt['Origin'][i]][3]+=1
            if dt['OpCarrier'][i]==carrier:
                carrier_dict[dt['Origin'][i]][0]+=dt['TotalPass'][i]
                carrier_dict[dt['Origin'][i]][2]+=1

            if dt['Dest'][i] in carrier_dict.keys():
                carrier_dict[dt['Dest'][i]][1]+=dt['TotalPass'][i]
                carrier_dict[dt['Dest'][i]][3]+=1
            if dt['OpCarrier'][i]==carrier:
                carrier_dict[dt['Dest'][i]][0]+=dt['TotalPass'][i]
                carrier_dict[dt['Dest'][i]][2]+=1
elif not passenger_filter_flag:
    if dt['Year'][i]==year_ and dt['Quarter'][i]==quarter_:
        if dt['Origin'][i] in carrier_dict.keys():
            carrier_dict[dt['Origin'][i]][1]+=dt['TotalPass'][i]
            carrier_dict[dt['Origin'][i]][3]+=1
        if dt['OpCarrier'][i]==carrier:
            carrier_dict[dt['Origin'][i]][0]+=dt['TotalPass'][i]
            carrier_dict[dt['Origin'][i]][2]+=1
        if dt['Dest'][i] in carrier_dict.keys():
            carrier_dict[dt['Dest'][i]][1]+=dt['TotalPass'][i]
            carrier_dict[dt['Dest'][i]][3]+=1
        if dt['OpCarrier'][i]==carrier:
            carrier_dict[dt['Dest'][i]][0]+=dt['TotalPass'][i]
            carrier_dict[dt['Dest'][i]][2]+=1

    for i in carrier_dict.keys():
        carrier_dict[i][4]=float(carrier_dict[i][0])/float(carrier_dict[i][1])
        carrier_dict[i][5]=float(carrier_dict[i][2])/float(carrier_dict[i][3])

    print year_; print quarter_; print carrier_dict; print

carrier_hub_passenger=[]; carrier_hub_route=[]
for i in carrier_dict.keys():
    carrier_hub_passenger.append([carrier_dict[i][4],i])
    carrier_hub_route.append([carrier_dict[i][5],i])
carrier_hub_passenger.sort()
carrier_hub_route.sort()

print; print 'Passenger'; print carrier_hub_passenger; print
print 'Route'; print carrier_hub_route

output_list=[]
for i in carrier_hub_passenger:
    if i[0]<0.3: output_list.append([i[1],'1','0','0','0'])
    elif i[0]>=0.3 and i[0]<0.5: output_list.append([i[1],'0','1','0','0'])
    elif i[0]>=0.5 and i[0]<0.7: output_list.append([i[1],'0','0','1','0'])
    elif i[0]>=0.7: output_list.append([i[1],'0','0','0','1'])

print; print output_list; print

full_airport_list=[]; filename3='region_by_airport.txt'
g=open(data_path+filename3,'r')
while 1==1:
    a=g.readline()
    b=a.split(' \
t')
    if len(b[0])==3: full_airport_list.append(b[0])
    if len(b[0])==0: break
g.close()

for k in full_airport_list:
    if k in carrier_airports: pass
    else: output_list.append([k,'1','0','0','0'])

if passenger_filter_flag:
    filename2=carrier+'_passenger_hub_'+year_+'_'+
    quarter_+'_passfilt.txt'
elif not passenger_filter_flag:
    filename2=carrier+'_passenger_hub_'+year_+'_'+quarter_+'.txt'

f=open(data_path+filename2,'w')
for i in output_list:
    output=''
    for j in i: output=output+j+'	'
    output=output+
    f.write(output)
    f.close()
import os, sys, pickle

module_dir = os.path.join('Project', 'code')
sys.path.insert(0, module_dir)

from airport_location_dict_generator import *

data_path = 'C:/Project/data/'

try:
    f = open(data_path + 'airport_locations_degrees_dict', 'r')
except IOError:
    create_location_dict()
    f = open(data_path + 'airport_locations_degrees_dict', 'r')

airport_locations_degrees_dict = pickle.load(f)
f.close()
def airport_location(iata_code):

    try:
        #print airport_locations_degrees_dict[iata_code][0]
        return airport_locations_degrees_dict[iata_code][1]
    except KeyError:
        print iata_code+' is not a valid code.'
        return

*******************************************************************************

# python_to_text

"""

WN_actual_routes_year_quarter, for WN entry model project.

Modified 13 January 2009 with airports excluded by the Wright Amend. (from DAL).
Modified 13 January 2009 with slot dummy.
Modified 14 January 2009 with major carrier hubs.
Modified 16 January 2009 with minor correction in list initializations.
Modified 17 January 2009 with passenger filter (manual).
Modified 17 January 2009 with arrival delay data (original data artificial CHI data).
Modified 17 January 2009 with distance ratio.
import cPickle, time, os, sys

module_dir=os.path.join('Project','code')
sys.path.insert(0,module_dir)

from safe_cPickle import *
from scipy import *

from airport_location_function_ import *

data_path='C:/Project/data/
#year_=['2007']; quarter_=['4']

passenger_filter_flag=True

fixed_year_quarter={‘2002_1’:0,’2002_2’:1,’2002_3’:2,’2002_4’:3,
   ’2003_1’:4,’2003_2’:5,’2003_3’:6,’2003_4’:7,\
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{'2004_1': 8, '2004_2': 9, '2004_3': 10, '2004_4': 11, \\
'2006_1': 16, '2006_2': 17, '2006_3': 18, '2006_4': 19, \\
'2007_1': 20, '2007_2': 21, '2007_3': 22, '2007_4': 23}

f = open(data_path + 'close_dict_0_50', 'r'); close_dict_0_50 = pickle.load(f); f.close()

f = open(data_path + 'close_dict_50_100', 'r'); close_dict_50_100 = pickle.load(f); f.close()

f = open(data_path + 'close_dict_100_150', 'r'); close_dict_100_150 = pickle.load(f); f.close()

f = open(data_path + 'service_since_dict', 'r'); service_since_dict = pickle.load(f); f.close()

f = open(data_path + 'jetblue_dict', 'r'); jetblue_dict = pickle.load(f); f.close()

f = open(data_path + 'frontier_dict', 'r'); frontier_dict = pickle.load(f); f.close()

f = open(data_path + 'airtran_dict', 'r'); airtran_dict = pickle.load(f); f.close()

f = open(data_path + 'alaska_dict', 'r'); alaska_dict = pickle.load(f); f.close()

filename = 'dep_delay_dict'

t01 = time.time(); print; print 'Loading dictionary: ' + filename

c_x_x = open(data_path + filename, 'r'); dep_delay_dict = cPickle.load(c_x_x)

print str(time.time() - t01) + ' seconds to load dictionary.'

c_x_x.close()

filename = 'arr_delay_dict'

t01 = time.time(); print; print 'Loading dictionary: ' + filename

c_x_x = open(data_path + filename, 'r'); arr_delay_dict = cPickle.load(c_x_x)
print str(time.time()-t01)+' seconds to load dictionary.'
c_x_x.close()

filename='carrier_airport_dict'
t01=time.time(); print; print 'Loading dictionary: '+filename
c_x_x=open(data_path+filename,'r'); carrier_airport_dict=cPickle.load(c_x_x)
print str(time.time()-t01)+' seconds to load dictionary.'
c_x_x.close()

for year in year_:
    for quarter in quarter_:

        if passenger_filter_flag:
            filename='WN_actual_routes_'+year+'_'+quarter+'_passfilt.txt'
        elif not passenger_filter_flag:
            filename='WN_actual_routes_'+year+'_'+quarter+'.txt'

        dt={}; t01=time.time(); print; print 'Parsing text file: '+filename

        keys=[carrier', route', year', quarter', passengers', distance', number', population', leisure', business', presence']

        for j in keys: dt[j]=[]
f=open(data_path+filename,'r')
while i==1:
    try:
        a=f.readline()
        b=a.split('	')
        dt['carrier'].append(b[0])
        dt['route'].append(b[1])
        dt['year'].append(b[2])
        dt['quarter'].append(b[3])
        dt['passengers'].append(b[4])
        dt['distance'].append(b[5])
        dt['number'].append(b[6])
        dt['population'].append(b[7])
        dt['leisure'].append(b[8])
        dt['business'].append(b[9])
        dt['presence'].append(b[10])
    except IndexError: break
print str(time.time()-t01)+' seconds to parse text file.'
f.close()

dt['region']=[]; region_dict={}; filename2='region_by_airport.txt'
t02=time.time(); print; print 'Loading airport region text file: '+filename2
g=open(data_path+filename2,'r')
while i==1:
    try:
a=g.readline()
b=a.split(’\t’)
region_dict[b[0]]=b[1].split(’\n’)[0]
except IndexError: break
print str(time.time()-t02)+’ seconds to parse text file.’
g.close()

region_pair_dict={'1_1':1,'1_2':2,'1_3':3,'1_4':4,'1_5':5,'2_2':6,
                 '2_3':7,'2_4':8,'2_5':9,'3_3':10,'3_4':11,
                 '3_5':12,'4_4':13,'4_5':14,'5_5':15}

for j in dt[’route’]:
c=[int(region_dict[j.split(’_’)[0]]),int(region_dict[j.split(’_’)[1]])]
c.sort()
d=str(c[0])+'_'+str(c[1])
catch_list=['0']*15
catch_list[region_pair_dict[d]-1]=’1’
dt[’region’].append(catch_list)

keys_=[’carrier’,’route’,’year’,’quarter’,’passengers’,’distance’,
       ’number’,’population’,’leisure’,’business’,’region1’,’region2’,
       ’region3’,’region4’,’region5’,’region6’,’region7’,’region8’,
       ’region9’,’region10’,’region11’,’region12’,’region13’,’region14’,
       ’region15’,’presence’]
dt_=\{
for k in keys_: dt_[k]=[]

for j in range(len(dt['carrier'])-1):
    for i in keys_
        if i[:6]!='region': dt_[i].append(dt[i][j])
        else: dt_[i].append(dt['region'][j][int(i[6:])-1])

hub_dict=\{

if passenger_filter_flag:
    filename4='WN_passenger_hub_+year+’_+quarter+’_passfilt.txt'
else not passenger_filter_flag:
    filename4='WN_passenger_hub_+year+’_+quarter+.txt'

f=open(data_path+filename4,'r')
while 1==1:
    a=f.readline()
    b=a.split(‘\t’)
    if len(b[0])==3: hub_dict[b[0]]=[b[1],b[2],b[3],b[4]]
    else: break

wright_dict=\{
filename4='wright_airports.txt'
t04=time.time(); print; print ’Parsing Wright Amend. text file: ’+filename4
```
g=open(data_path+filename4,'r')
while 1==1:
    a=g.readline()
    b=a.split(\'\t\')
    if len(b[0])==3: wright_dict[b[0]]=b[1].split(\'\n\')[0]
    else: break

print str(time.time()-t04)+\' seconds to parse text file.\'
g.close()

slot_dict={}  
filename5=\'slot_restricted.txt\'
t05=time.time(); print; print \'Parsing slot restricted text file: \'+filename5
g=open(data_path+filename5,'r')
while 1==1:
    a=g.readline()
    b=a.split(\'\t\')
    if len(b[0])==3: slot_dict[b[0]]=b[1].split(\'\n\')[0]
    else: break

print str(time.time()-t05)+\' seconds to parse text file.\'
g.close()

aa_hub_dict={}  

if passenger_filter_flag:
    filename6=\'AA_passenger_hub\'+year+\'_\'+quarter+\'_passfilt.txt\'
```
elif not passenger_filter_flag:
    filename6='AA_passenger_hub_’+year+’_’+quarter+’’.txt’

    t06=time.time(); print; print 'Parsing major hub text file: ’+filename6
    g=open(data_path+filename6,’r’)
    while 1==1:
        a=g.readline()
        b=a.split(’\t’)
        if len(b[0])==3: aa_hub_dict[b[0]]=b[1],b[2],b[3],b[4]]
        else: break

    print str(time.time()-t06)+’ seconds to parse text file.’
    g.close()

    us_hub_dict={}

    if passenger_filter_flag:
        filename6=’US_passenger_hub_’+year+’_’+quarter+’_passfilt.txt’
    elif not passenger_filter_flag:
        filename6=’US_passenger_hub_’+year+’_’+quarter+’’.txt’

    t06=time.time(); print; print 'Parsing major hub text file: ’+filename6
    g=open(data_path+filename6,’r’)
    while 1==1:
        a=g.readline()
        b=a.split(’\t’)
if len(b[0])==3: us_hub_dict[b[0]]=[b[1],b[2],b[3],b[4]]
else: break
print str(time.time()-t06)+' seconds to parse text file.'
g.close()

ua_hub_dict={}

if passenger_filter_flag:
    filename6='UA_passenger_hub_')+year+''+quarter+'_'+passfilt.txt'
elif not passenger_filter_flag:
    filename6='UA_passenger_hub_')+year+''+quarter+'.txt'

t06=time.time(); print; print 'Parsing major hub text file: '+filename6
g=open(data_path+filename6,'r')
while 1==1:
a=g.readline()
b=a.split('t')
if len(b[0])==3: ua_hub_dict[b[0]]=[b[1],b[2],b[3],b[4]]
else: break
print str(time.time()-t06)+' seconds to parse text file.'
g.close()

nw_hub_dict={}

if passenger_filter_flag:
filename6='NW_passenger_hub_’+year+’’+quarter+’’_passfilt.txt’

elif not passenger_filter_flag:
    filename6='NW_passenger_hub_’+year+’’+quarter+’’.txt’

t06=time.time(); print; print 'Parsing major hub text file: ’+filename6
g=open(data_path+filename6,’r’)

while 1==1:
    a=g.readline()
    b=a.split(‘\t’)
    if len(b[0])==3: nw_hub_dict[b[0]]=b[1],b[2],b[3],b[4]]
    else: break

print str(time.time()-t06)+’ seconds to parse text file.’
g.close()

dl_hub_dict={}

if passenger_filter_flag:
    filename6='DL_passenger_hub_’+year+’’+quarter+’’_passfilt.txt’
else not passenger_filter_flag:
    filename6='DL_passenger_hub_’+year+’’+quarter+’’.txt’

t06=time.time(); print; print 'Parsing major hub text file: ’+filename6
g=open(data_path+filename6,’r’)

while 1==1:
    a=g.readline()
b=a.split(\'\t\')
if len(b[0])\==3: dl_hub_dict[b[0]]=\[b[1],b[2],b[3],b[4]\]
else: break
print str(time.time()-t06)+\' seconds to parse text file.\'
g.close()

co_hub_dict={} 

if passenger_filter_flag:
    filename6=\'CO_passenger_hub_\'+year+\'_\'+quarter+\'\_passfilt.txt\'
elif not passenger_filter_flag:
    filename6=\'CO_passenger_hub_\'+year+\'_\'+quarter+\'.txt\'

t06=time.time(); print; print \'Parsing major hub text file: \'+filename6
g=open(data_path+filename6,\'r\')
while 1==1:
    a=g.readline()
    b=a.split(\'\t\')
    if len(b[0])\==3: co_hub_dict[b[0]]=\[b[1],b[2],b[3],b[4]\]
    else: break
print str(time.time()-t06)+\' seconds to parse text file.\'
g.close()

keys_=\[\'carrier\',\'route\',\'year\',\'quarter\',\'passengers\',\'distance\',\n    \'number\',\'population\',\'leisure\',\'business\',\'region1\',\'region2\',\n
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'region3', 'region4', 'region5', 'region6', 'region7', 'region8', \\n'region9', 'region10', 'region11', 'region12', 'region13', 'region14', \\n'region15', 'pass_hub_1', 'pass_hub_2', 'pass_hub_3', 'pass_hub_4', \\n'wright', 'slot', 'aa_pass_hub_1', 'aa_pass_hub_2', 'aa_pass_hub_3', \\n'aa_pass_hub_4', 'us_pass_hub_1', 'us_pass_hub_2', 'us_pass_hub_3', \\n'us_pass_hub_4', 'ua_pass_hub_1', 'ua_pass_hub_2', 'ua_pass_hub_3', \\n'ua_pass_hub_4', 'nw_pass_hub_1', 'nw_pass_hub_2', 'nw_pass_hub_3', \\n'nw_pass_hub_4', 'dl_pass_hub_1', 'dl_pass_hub_2', 'dl_pass_hub_3', \\n'dl_pass_hub_4', 'co_pass_hub_1', 'co_pass_hub_2', 'co_pass_hub_3', \\n'co_pass_hub_4', 'hub_0_50', 'hub_50_100', 'hub_100_150', \\n'nearby_route_0_50', 'nearby_route_50_100', \\n'nearby_endpoint_0_50', 'nearby_endpoint_50_100', \\nn_, 'aa_pass_hub', 'us_pass_hub', 'ua_pass_hub', \\nw_pass_hub', 'dl_pass_hub', 'co_pass_hub', 'max_dep_delay', \\n'max_arr_delay', 'max_delay', 'distance_ratio', \\n'jetblue', 'airtran', 'frontier', 'alaska', 'service_since', \\npresence']

dt_['pass_hub_4']=[]; dt_['pass_hub_3']=[]
dt_['pass_hub_2']=[]; dt_['pass_hub_1']=[]
dt_['wright']=[]; dt_['slot']=[]; dt_['n_']=[]
dt_['aa_pass_hub_4']=[]; dt_['aa_pass_hub_3']=[]
dt_['aa_pass_hub_2']=[]; dt_['aa_pass_hub_1']=[]
dt_['us_pass_hub_4']=[]; dt_['us_pass_hub_3']=[]
dt_['us_pass_hub_2']=[]; dt_['us_pass_hub_1']=[]
dt_['ua_pass_hub_4']=[]; dt_['ua_pass_hub_3']=[]
dt_['ua_pass_hub_2']=[]; dt_['ua_pass_hub_1']=[]
dt_['nw_pass_hub_4']=[]; dt_['nw_pass_hub_3']=[]
dt_['nw_pass_hub_2']=[]; dt_['nw_pass_hub_1']=[]
dt_['dl_pass_hub_4']=[]; dt_['dl_pass_hub_3']=[]
dt_['dl_pass_hub_2']=[]; dt_['dl_pass_hub_1']=[]
dt_['co_pass_hub_4']=[]; dt_['co_pass_hub_3']=[]
dt_['co_pass_hub_2']=[]; dt_['co_pass_hub_1']=[]

dt_['hub_0_50']=[]; dt_['hub_50_100']=[]; dt_['hub_100_150']=[]

dt_['nearby_route_0_50']=[]; dt_['nearby_route_50_100']=[]
dt_['nearby_route_100_150']=[]; dt_['nearby_endpoint_0_50']=[]
dt_['nearby_endpoint_50_100']=[]; dt_['nearby_endpoint_100_150']=[]

dt_['max_dep_delay']=[]; dt_['max_arr_delay']=[]; dt_['max_delay']=[]

dt_['aa_pass_hub']=[]; dt_['us_pass_hub']=[]; dt_['ua_pass_hub']=[]
dt_['nw_pass_hub']=[]; dt_['dl_pass_hub']=[]; dt_['co_pass_hub']=[]

dt_['distance_ratio']=[]; dt_['service_since']=[]

dt_['jetblue']=[]; dt_['airtran']=[]
dt_['frontier']=[]; dt_['alaska']=[]

route_dist_dict={}; route_pass_dict={}

for i in range(len(dt_['carrier'])):
    ""
    dt_['service_since'].append(str(service_since_dict[dt_['route'][i].split('_')[0]][fixed_year[year]]+
                     service_since_dict[dt_['route'][i].split('_')[1]]
                     [fixed_year[year]]))
    ""
    dt_['service_since'].append(str(max(service_since_dict[dt_['route'][i].split('_')[0]][fixed_year[year]],
                     service_since_dict[dt_['route'][i].split('_')[1]]
                     [fixed_year[year]])))

    if dt_['presence'][i].split('
')[0]=='1':
        if dt_['route'][i].split('_')[0] not in route_dist_dict.keys():
            route_dist_dict[dt_['route'][i].split('_')[0]]=
                [[eval(dt_['distance'][i]),eval(dt_['passengers'][i])]]
            route_pass_dict[dt_['route'][i].split('_')[0]]=
                eval(dt_['passengers'][i])
elif dt_['route'][i].split('_')[0] in route_dist_dict.keys():
    route_dist_dict[dt_['route'][i].split('_')[0]].append(
        [eval(dt_['distance'][i]),eval(dt_['passengers'][i])]
    )
    route_pass_dict[dt_['route'][i].split('_')[0]] =
    route_pass_dict[dt_['route'][i].split('_')[0]] +
    eval(dt_['passengers'][i])
else: pass

if dt_['presence'][i].split('
')[0] == '1':
    if dt_['route'][i].split('_')[1] not in route_dist_dict.keys():
        route_dist_dict[dt_['route'][i].split('_')[1]] =
        [[eval(dt_['distance'][i]),eval(dt_['passengers'][i])]]
        route_pass_dict[dt_['route'][i].split('_')[1]] =
        eval(dt_['passengers'][i])
    elif dt_['route'][i].split('_')[1] in route_dist_dict.keys():
        route_dist_dict[dt_['route'][i].split('_')[1]].append(
            [eval(dt_['distance'][i]),eval(dt_['passengers'][i])]
        )
        route_pass_dict[dt_['route'][i].split('_')[1]] =
        route_pass_dict[dt_['route'][i].split('_')[1]] +
        eval(dt_['passengers'][i])
else: pass

elif dt_['route'][i].split('_')[1] in route_dist_dict.keys():
    route_dist_dict[dt_['route'][i].split('_')[1]].append(
        [eval(dt_['distance'][i]),eval(dt_['passengers'][i])]
    )
    route_pass_dict[dt_['route'][i].split('_')[1]] =
    route_pass_dict[dt_['route'][i].split('_')[1]] +
    eval(dt_['passengers'][i])
else: pass

""

dt_['jetblue'].append(str(max(jetblue_dict[
    [dt_['route'][i].split('_')[0]] [fixed_year][year]],
    ...
jetblue_dict[dt_['route'][i].split('_')[1]] [fixed_year[year]])
}
dt_['frontier'].append(str(max(frontier_dict
[dt_['route'][i].split('_')[0]] [fixed_year[year]],
    frontier_dict[dt_['route'][i].split('_')[1]] [fixed_year[year]])
)
dt_['airtran'].append(str(max(airtran_dict
[dt_['route'][i].split('_')[0]] [fixed_year[year]],
    airtran_dict[dt_['route'][i].split('_')[1]] [fixed_year[year]])
)

dt_['alaska'].append(str(max(alaska_dict
[dt_['route'][i].split('_')[0]] [fixed_year[year]],
    alaska_dict[dt_['route'][i].split('_')[1]] [fixed_year[year]])
)

"""

dt_['jetblue'].append(str(max(jetblue_dict
[dt_['route'][i].split('_')[0]] [fixed_year_quarter[year+'_'+quarter]],jetblue_dict[dt_['route'][i].split\('_')[1]] [fixed_year_quarter[year+'_'+quarter]])
)
dt_['frontier'].append(str(max(frontier_dict
[dt_['route'][i].split('_')[0]] [fixed_year_quarter[year+'_'+quarter]],frontier_dict[dt_['route'][i].split\('_')[1]] [fixed_year_quarter[year+'_'+quarter]])
)
dt_['airtran'].append(str(max(airtran_dict
[dt_['route'][i].split('_')[0]] [fixed_year_quarter[year+'_'+quarter]],airtran_dict[dt_['route'][i].split\('_')[1]] [fixed_year_quarter[year+'_'+quarter]])
)
dt_['alaska'].append(str(max(alaska_dict
[dt_['route'][i].split('_')[0]] [fixed_year_quarter[year+'_'+quarter]],alaska_dict[dt_['route'][i].split\('_')[1]] [fixed_year_quarter[year+'_'+quarter]])
)
if hub_dict[dt_['route'][i].split('_')[0]].index('1')>=
hub_dict[dt_['route'][i].split('_')[1]].index('1):
    cc=hub_dict[dt_['route'][i].split('_')[0]]
else: cc=hub_dict[dt_['route'][i].split('_')[1]]

if hub_dict[dt_['route'][i].split('_')[0]].index('1')>=
hub_dict[dt_['route'][i].split('_')[1]].index('1'):
    cc=hub_dict[dt_['route'][i].split('_')[0]]
else: cc=hub_dict[dt_['route'][i].split('_')[1]]

dt_['pass_hub_4'].append(cc[3]); dt_['pass_hub_3'].append(cc[2])
dt_['pass_hub_2'].append(cc[1]); dt_['pass_hub_1'].append(cc[0])

if dt_['route'][i].split('_')[0]==''DAL':
    dt_['wright'].append(wright_dict[dt_['route'][i].split('_')[1]])
elif dt_['route'][i].split('_')[1]==''DAL':

dt_['wright'].append(wright_dict[dt_['route'][i].split('_')[0]])
else: dt_['wright'].append('0')

if (slot_dict[dt_['route'][i].split('_')[0]]=='1') or (slot_dict[dt_['route'][i].split('_')[1]]=='1'):
    dt_['slot'].append('1')
else: dt_['slot'].append('0')

if aa_hub_dict[dt_['route'][i].split('_')[0]].index('1')>=
    aa_hub_dict[dt_['route'][i].split('_')[1]].index('1'):
    cc=aa_hub_dict[dt_['route'][i].split('_')[0]]
else: cc=aa_hub_dict[dt_['route'][i].split('_')[1]]

dt_['aa_pass_hub_4'].append(cc[3]); dt_['aa_pass_hub_3'].append(cc[2])
dt_['aa_pass_hub_2'].append(cc[1]); dt_['aa_pass_hub_1'].append(cc[0])

if us_hub_dict[dt_['route'][i].split('_')[0]].index('1')>=
    us_hub_dict[dt_['route'][i].split('_')[1]].index('1'):
    cc=us_hub_dict[dt_['route'][i].split('_')[0]]
else: cc=us_hub_dict[dt_['route'][i].split('_')[1]]

dt_['us_pass_hub_4'].append(cc[3])
dt_['us_pass_hub_3'].append(cc[2])
dt_['us_pass_hub_2'].append(cc[1])
dt_['us_pass_hub_1'].append(cc[0])
if ua_hub_dict[dt_['route'][i].split('_')[0]].index('1')>=\
    ua_hub_dict[dt_['route'][i].split('_')[1]].index('1'):
    cc=ua_hub_dict[dt_['route'][i].split('_')[0]]
else: cc=ua_hub_dict[dt_['route'][i].split('_')[1]]
dt_['ua_pass_hub_4'].append(cc[3]); dt_['ua_pass_hub_3'].append(cc[2])
dt_['ua_pass_hub_2'].append(cc[1]); dt_['ua_pass_hub_1'].append(cc[0])

if nw_hub_dict[dt_['route'][i].split('_')[0]].index('1')>=\
    nw_hub_dict[dt_['route'][i].split('_')[1]].index('1'):
    cc=nw_hub_dict[dt_['route'][i].split('_')[0]]
else: cc=nw_hub_dict[dt_['route'][i].split('_')[1]]
dt_['nw_pass_hub_4'].append(cc[3]); dt_['nw_pass_hub_3'].append(cc[2])
dt_['nw_pass_hub_2'].append(cc[1]); dt_['nw_pass_hub_1'].append(cc[0])

if dl_hub_dict[dt_['route'][i].split('_')[0]].index('1')>=\
    dl_hub_dict[dt_['route'][i].split('_')[1]].index('1'):
    cc=dl_hub_dict[dt_['route'][i].split('_')[0]]
else: cc=dl_hub_dict[dt_['route'][i].split('_')[1]]
dt_['dl_pass_hub_4'].append(cc[3]); dt_['dl_pass_hub_3'].append(cc[2])
dt_['dl_pass_hub_2'].append(cc[1]); dt_['dl_pass_hub_1'].append(cc[0])

if co_hub_dict[dt_['route'][i].split('_')[0]].index('1')>=\
co_hub_dict[dt_['route'][i].split('_')[1]].index('1'):
cc=co_hub_dict[dt_['route'][i].split('_')[0]]
else: cc=co_hub_dict[dt_['route'][i].split('_')[1]]

dt_['co_pass_hub_4'].append(cc[3]); dt_['co_pass_hub_3'].append(cc[2])
dt_['co_pass_hub_2'].append(cc[1]); dt_['co_pass_hub_1'].append(cc[0])

flag=0

hub_major_0=['0']*18; hub_major_1=['0']*18

if close_dict_0_50[dt_['route'][i].split('_')[0]]!=[]:
    hub_major_0=[dt_['co_pass_hub_4'][i],dt_['co_pass_hub_3'][i],
    dt_['co_pass_hub_2'][i],dt_['dl_pass_hub_4'][i],
    dt_['dl_pass_hub_3'][i],dt_['dl_pass_hub_2'][i],
    dt_['nw_pass_hub_4'][i],dt_['nw_pass_hub_3'][i],
    dt_['nw_pass_hub_2'][i],dt_['ua_pass_hub_4'][i],
    dt_['ua_pass_hub_3'][i],dt_['ua_pass_hub_2'][i],
    dt_['us_pass_hub_4'][i],dt_['us_pass_hub_3'][i],
    dt_['us_pass_hub_2'][i],dt_['aa_pass_hub_4'][i],
    dt_['aa_pass_hub_3'][i],dt_['aa_pass_hub_2'][i]]

if close_dict_0_50[dt_['route'][i].split('_')[1]]!=[]:
    hub_major_1=[dt_['co_pass_hub_4'][i],dt_['co_pass_hub_3'][i],
    dt_['co_pass_hub_2'][i],dt_['dl_pass_hub_4'][i],
    dt_['dl_pass_hub_3'][i],dt_['dl_pass_hub_2'][i],
    dt_['nw_pass_hub_4'][i],dt_['nw_pass_hub_3'][i],
    dt_['nw_pass_hub_2'][i],dt_['ua_pass_hub_4'][i],
    dt_['ua_pass_hub_3'][i],dt_['ua_pass_hub_2'][i],
    dt_['us_pass_hub_4'][i],dt_['us_pass_hub_3'][i],
    dt_['us_pass_hub_2'][i],dt_['aa_pass_hub_4'][i],
    dt_['aa_pass_hub_3'][i],dt_['aa_pass_hub_2'][i]]
if close_dict_0_50[dt_['route'][i].split('_')[0]]!=[] or close_dict_0_50[dt_['route'][i].split('_')[1]]!=[]:
    hub_major=hub_major_0+hub_major_1
    if hub_major.count('1')!=0: flag=1

if flag==1: dt_['hub_0_50'].append('1')
el:se: dt_['hub_0_50'].append('0')
flag=0

hub_major_0=['0']*18; hub_major_1=['0']*18

if close_dict_50_100[dt_['route'][i].split('_')[0]]!=[]:
    hub_major_0=[dt_['co_pass_hub_4'][i], dt_['co_pass_hub_3'][i],
                 dt_['co_pass_hub_2'][i], dt_['dl_pass_hub_4'][i],
                 dt_['dl_pass_hub_3'][i], dt_['dl_pass_hub_2'][i],
                 dt_['nw_pass_hub_4'][i], dt_['nw_pass_hub_3'][i],
                 dt_['us_pass_hub_4'][i], dt_['us_pass_hub_3'][i],
                 dt_['ua_pass_hub_4'][i], dt_['ua_pass_hub_3'][i],
                 dt_['us_pass_hub_2'][i], dt_['aa_pass_hub_4'][i],
                 dt_['aa_pass_hub_3'][i], dt_['aa_pass_hub_2'][i]]

    if close_dict_0_50[dt_['route'][i].split('_')[0]]!=[] or close_dict_0_50[dt_['route'][i].split('_')[1]]!=[]:
        hub_major=hub_major_0+hub_major_1
        if hub_major.count('1')!=0: flag=1

if flag==1: dt_['hub_0_50'].append('1')
el:se: dt_['hub_0_50'].append('0')
flag=0

hub_major_0=['0']*18; hub_major_1=['0']*18

if close_dict_50_100[dt_['route'][i].split('_')[0]]!=[]:
    hub_major_0=[dt_['co_pass_hub_4'][i], dt_['co_pass_hub_3'][i],
                 dt_['co_pass_hub_2'][i], dt_['dl_pass_hub_4'][i],
                 dt_['dl_pass_hub_3'][i], dt_['dl_pass_hub_2'][i],
                 dt_['nw_pass_hub_4'][i], dt_['nw_pass_hub_3'][i],
                 dt_['us_pass_hub_4'][i], dt_['us_pass_hub_3'][i],
                 dt_['ua_pass_hub_4'][i], dt_['ua_pass_hub_3'][i],
                 dt_['us_pass_hub_2'][i], dt_['aa_pass_hub_4'][i],
                 dt_['aa_pass_hub_3'][i], dt_['aa_pass_hub_2'][i]]
dt_['nw_pass_hub_2'][i], dt_['ua_pass_hub_4'][i],
dt_['ua_pass_hub_3'][i], dt_['ua_pass_hub_2'][i],
dt_['us_pass_hub_4'][i], dt_['us_pass_hub_3'][i],
dt_['us_pass_hub_2'][i], dt_['aa_pass_hub_4'][i],
dt_['aa_pass_hub_3'][i], dt_['aa_pass_hub_2'][i]]

if close_dict_50_100[dt_['route'][i].split('_')[1]]!=[]:
    hub_major_1=[dt_['co_pass_hub_4'][i], dt_['co_pass_hub_3'][i],
    dt_['co_pass_hub_2'][i], dt_['dl_pass_hub_4'][i],
    dt_['dl_pass_hub_3'][i], dt_['dl_pass_hub_2'][i],
    dt_['nw_pass_hub_4'][i], dt_['nw_pass_hub_3'][i],
    dt_['nw_pass_hub_2'][i], dt_['ua_pass_hub_4'][i],
    dt_['ua_pass_hub_3'][i], dt_['ua_pass_hub_2'][i],
    dt_['us_pass_hub_4'][i], dt_['us_pass_hub_3'][i],
    dt_['us_pass_hub_2'][i], dt_['aa_pass_hub_4'][i],
    dt_['aa_pass_hub_3'][i], dt_['aa_pass_hub_2'][i]]

if close_dict_50_100[dt_['route'][i].split('_')[0]]!=[] or
   close_dict_50_100[dt_['route'][i].split('_')[1]]!=[]:
    hub_major=hub_major_0+hub_major_1
    if hub_major.count('1')!=0: flag=1

if flag==1: dt_['hub_50_100'].append('1')
else: dt_['hub_50_100'].append('0')
flag=0

hub_major_0=['0']*18; hub_major_1=['0']*18

if close_dict_100_150[dt_['route'][i].split('_')[0]]!=[]:
    hub_major_0=dt_['co_pass_hub_4'][i],dt_['co_pass_hub_3'][i],
    dt_['co_pass_hub_2'][i],dt_['dl_pass_hub_4'][i],
    dt_['dl_pass_hub_3'][i],dt_['dl_pass_hub_2'][i],
    dt_['nw_pass_hub_4'][i],dt_['nw_pass_hub_3'][i],
    dt_['nw_pass_hub_2'][i],dt_['ua_pass_hub_4'][i],
    dt_['ua_pass_hub_3'][i],dt_['ua_pass_hub_2'][i],
    dt_['us_pass_hub_4'][i],dt_['us_pass_hub_3'][i],
    dt_['us_pass_hub_2'][i],dt_['aa_pass_hub_4'][i],
    dt_['aa_pass_hub_3'][i],dt_['aa_pass_hub_2'][i]]

if close_dict_100_150[dt_['route'][i].split('_')[1]]!=[]:
    hub_major_1=dt_['co_pass_hub_4'][i],dt_['co_pass_hub_3'][i],
    dt_['co_pass_hub_2'][i],dt_['dl_pass_hub_4'][i],
    dt_['dl_pass_hub_3'][i],dt_['dl_pass_hub_2'][i],
    dt_['nw_pass_hub_4'][i],dt_['nw_pass_hub_3'][i],
    dt_['nw_pass_hub_2'][i],dt_['ua_pass_hub_4'][i],
    dt_['ua_pass_hub_3'][i],dt_['ua_pass_hub_2'][i],
    dt_['us_pass_hub_4'][i],dt_['us_pass_hub_3'][i],
    dt_['us_pass_hub_2'][i],dt_['aa_pass_hub_4'][i],
    dt_['aa_pass_hub_3'][i],dt_['aa_pass_hub_2'][i]]
if close_dict_100_150[dt_['route'][i].split('_')[0]] != [] or 
  close_dict_100_150[dt_['route'][i].split('_')[1]] != []:
    hub_major = hub_major_0 + hub_major_1
    if hub_major.count('1') != 0: flag = 1

if flag == 1: dt_['hub_100_150'].append('1')
else: dt_['hub_100_150'].append('0')

flagg = 0
if close_dict_0_50[dt_['route'][i].split('_')[0]] != [] and 
  close_dict_0_50[dt_['route'][i].split('_')[1]] != []:
  for aa in close_dict_0_50[dt_['route'][i].split('_')[0]]:
    for bb in close_dict_0_50[dt_['route'][i].split('_')[1]]:
      if aa != bb:
        close_list = [aa, bb]
        close_list.sort()
        if dt_['presence'][dt_['route'].index(close_list[0] + '_' + close_list[1])].split('
')[0] == '1':
          flagg = 1

if flagg: dt_['nearby_route_0_50'].append('1')
else: dt_['nearby_route_0_50'].append('0')

flagg = 0
if close_dict_50_100[dt_['route'][i].split('_')[0]] != [] and 
  close_dict_50_100[dt_['route'][i].split('_')[1]] != []:
for aa in close_dict_50_100[dt_['route'][i].split('_')[0]]:
    for bb in close_dict_50_100[dt_['route'][i].split('_')[1]]:
        if aa!=bb:
            close_list=[aa,bb]
            close_list.sort()
        if dt_['presence'][dt_['route'].index(close_list[0]+'_'.join(close_list[1]))].split('
')[0]=='1':
            flagg=1
if flagg: dt_['nearby_route_50_100'].append('1')
else: dt_['nearby_route_50_100'].append('0')


flag=0
if close_dict_100_150[dt_['route'][i].split('_')[0]]!=[] and 
    close_dict_100_150[dt_['route'][i].split('_')[1]]!=[] :
    for aa in close_dict_100_150[dt_['route'][i].split('_')[0]]:
        for bb in close_dict_100_150[dt_['route'][i].split('_')[1]]:
            if aa!=bb:
                close_list=[aa,bb]
                close_list.sort()
            if dt_['presence'][dt_['route'].index(close_list[0]+'_'.join(close_list[1]))].split('
')[0]=='1':
                flagg=1
if flagg: dt_['nearby_route_100_150'].append('1')
else: dt_['nearby_route_100_150'].append('0')

""

flagg=0
if close_dict_0_50[dt_['route'][i].split('_')[0]]!={} and not (close_dict_0_50[dt_['route'][i].split('_')[0]]!={}) and close_dict_0_50[dt_['route'][i].split('_')[1]]!={}
    for aa in close_dict_0_50[dt_['route'][i].split('_')[0]]:
        if aa!=dt_['route'][i].split('_')[1]:
            close_list=[aa,dt_['route'][i].split('_')[1]]
            close_list.sort()
            if dt_['presence'][dt_.index(close_list[0]+
                                '_' +close_list[1])].split('
')[0]=='1':
                flagg=1
if close_dict_0_50[dt_['route'][i].split('_')[1]]!={} and not (close_dict_0_50[dt_['route'][i].split('_')[0]]!={}) and close_dict_0_50[dt_['route'][i].split('_')[1]]!={}
    for aa in close_dict_0_50[dt_['route'][i].split('_')[1]]:
        if aa!=dt_['route'][i].split('_')[0]:
            close_list=[aa,dt_['route'][i].split('_')[0]]
            close_list.sort()
            if dt_['presence'][dt_.index(close_list[0]+
                                '_' +close_list[1])].split('
')[0]=='1':
                flagg=1
if flagg: dt_['nearby_endpoint_0_50'].append('1')
else: dt_['nearby_endpoint_0_50'].append('0')

flagg=0
if close_dict_50_100[dt_['route'][i].split('_')[0]]!=[] and not
   (close_dict_50_100[dt_['route'][i].split('_')[0]]!=[] and
    close_dict_50_100[dt_['route'][i].split('_')[1]]!=[]):
   for aa in close_dict_50_100[dt_['route'][i].split('_')[0]]:
      if aa!=dt_['route'][i].split('_')[1]:
         close_list=[aa,dt_['route'][i].split('_')[1]]
         close_list.sort()
         if dt_['presence'][dt_.index(close_list[0]+'_'+
                             close_list[1])].split('
')[0]=='1':
            flagg=1
if close_dict_50_100[dt_['route'][i].split('_')[1]]!=[] and not
   (close_dict_50_100[dt_['route'][i].split('_')[0]]!=[] and
    close_dict_50_100[dt_['route'][i].split('_')[1]]!=[]):
   for aa in close_dict_50_100[dt_['route'][i].split('_')[1]]:
      if aa!=dt_['route'][i].split('_')[0]:
         close_list=[aa,dt_['route'][i].split('_')[0]]
         close_list.sort()
         if dt_['presence'][dt_.index(close_list[0]+'_'+
                             close_list[1])].split('
')[0]=='1':
            flagg=1
if flagg: dt_['nearby_endpoint_50_100'].append('1')
else: dt_['nearby_endpoint_50_100'].append('0')
flagg = 0

if close_dict_100_150[dt_['route'][i].split('_')[0]] != [] and not
(close_dict_100_150[dt_['route'][i].split('_')[0]] != [] and
close_dict_100_150[dt_['route'][i].split('_')[1]] != []):
    for aa in close_dict_100_150[dt_['route'][i].split('_')[0]]:
        if aa != dt_['route'][i].split('_')[1]:
            close_list = [aa, dt_['route'][i].split('_')[1]]
            close_list.sort()
            if dt_['presence'][dt_.index(close_list[0] + '_' +
close_list[1])].split('
')[0] == '1':
                flagg = 1

if close_dict_100_150[dt_['route'][i].split('_')[1]] != [] and not
(close_dict_100_150[dt_['route'][i].split('_')[0]] != [] and
close_dict_100_150[dt_['route'][i].split('_')[1]] != []):
    for aa in close_dict_100_150[dt_['route'][i].split('_')[1]]:
        if aa != dt_['route'][i].split('_')[0]:
            close_list = [aa, dt_['route'][i].split('_')[0]]
            close_list.sort()
            if dt_['presence'][dt_.index(close_list[0] + '_' +
close_list[1])].split('
')[0] == '1':
                flagg = 1

if flagg: dt_['nearby_endpoint_100_150'].append('1')
else: dt_['nearby_endpoint_100_150'].append('0')
Appendix

```python
# Code snippet

dt_['max_dep_delay'].append(str(max(dep_delay_dict[dt_['route'][i].split('_')[0]].split('_')[0][fixed_year[year]],
                         dep_delay_dict[dt_['route'][i].split('_')[1]].split('_')[1][fixed_year[year]])))

dt_['max_arr_delay'].append(str(max(arr_delay_dict[dt_['route'][i].split('_')[0]].split('_')[0][fixed_year[year]],
                                 arr_delay_dict[dt_['route'][i].split('_')[1]].split('_')[1][fixed_year[year]])))

dt_['max_delay'].append(str(max(max(dep_delay_dict[dt_['route'][i].split('_')[0]].split('_')[0][fixed_year[year]],
                                   dep_delay_dict[dt_['route'][i].split('_')[1]].split('_')[1][fixed_year[year]]),
                              max(arr_delay_dict[dt_['route'][i].split('_')[0]].split('_')[0][fixed_year[year]],
                                  arr_delay_dict[dt_['route'][i].split('_')[1]].split('_')[1][fixed_year[year]]))))

dt_['n_'].append(str(float(dt_['number'][i]) - float(dt_['presence'][i])))

dt_['aa_pass_hub'].append(str(float(dt_['aa_pass_hub_2'][i]) +
                          float(dt_['aa_pass_hub_3'][i]) + float(dt_['aa_pass_hub_4'][i])))

dt_['us_pass_hub'].append(str(float(dt_['us_pass_hub_2'][i]) +
                          float(dt_['us_pass_hub_3'][i]) + float(dt_['us_pass_hub_4'][i])))

dt_['ua_pass_hub'].append(str(float(dt_['ua_pass_hub_2'][i]) +
                          float(dt_['ua_pass_hub_3'][i]) + float(dt_['ua_pass_hub_4'][i])))
```

"""
float(dt_['ua_pass_hub_3'][i])+float(dt_['ua_pass_hub_4'][i]))

dt_['nw_pass_hub'].append(str(float(dt_['nw_pass_hub_2'][i])+\
float(dt_['nw_pass_hub_3'][i])+float(dt_['nw_pass_hub_4'][i])))

dt_['dl_pass_hub'].append(str(float(dt_['dl_pass_hub_2'][i])+\
float(dt_['dl_pass_hub_3'][i])+float(dt_['dl_pass_hub_4'][i])))

dt_['co_pass_hub'].append(str(float(dt_['co_pass_hub_2'][i])+\
float(dt_['co_pass_hub_3'][i])+float(dt_['co_pass_hub_4'][i])))

av_dict={}

for kk in route_dist_dict.keys():
    count_=0
    for ll in route_dist_dict[kk]:
        count_+=(float(ll[1])/float(route_pass_dict[kk]))*float(ll[0])
    av_dict[kk]=count_

r_=6372.7974775959065

for i in range(len(dt_['carrier'])):
    c_r=[dt_['route'][i].split('_')[0],dt_['route'][i].split('_')[1]]
    c_r.sort()

    if c_r[0] in av_dict.keys():
        ccr0=float(av_dict[c_r[0]])
    else:
        ccr0=0.0

    if c_r[1] in av_dict.keys():
        ccr1=float(av_dict[c_r[1]])
    else:
        ccr1=0.0
\[ p1,11=(\pi/180)\cdot\text{airport\_location}(c_r[0])[0],\]
\[ (\pi/180)\cdot\text{airport\_location}(c_r[0])[1] \]
\[ p2,12=(\pi/180)\cdot\text{airport\_location}(c_r[1])[0],\]
\[ (\pi/180)\cdot\text{airport\_location}(c_r[1])[1] \]
\[ l=\text{abs}(11-12) \]
\[ \text{num}=\sqrt{(((\cos(p2)\cdot\sin(1))^{**2})+(((\cos(p1)\cdot\sin(p2))-\}
\[ (\sin(p1)\cdot\cos(p2)\cdot\cos(1)))^{**2}))} \]
\[ \text{den}=\sin(p1)\cdot\sin(p2)+\cos(p1)\cdot\cos(p2)\cdot\cos(1) \]
\[ \text{theta}=\text{arctan}(\text{num/den}) \]
\[ \text{distance\_}=\text{abs}(\text{int(round}(r_\cdot\text{theta}))) \]
\[ \text{dt\_[distance\_ratio].append(str(mean([ccr0,ccr1])/float(distance\_)))} \]

if passenger_filter_flag:
    filename3=’WN\_actual\_routes\_’+year+’\_’+quarter+’\_passfilt\_.txt’
eelif not passenger_filter_flag:
    filename3=’WN\_actual\_routes\_’+year+’\_’+quarter+’\_.txt’

t03=time.time(); print; print ’Writing output text file: ’+filename3
g=open(data\_path+filename3,’w’)
for j in range(len(dt_’carrier’)):  
    output=’’ 
    for i in keys__:
        output=output+dt_[i][j]
        if output[-1]!)=’\n’: output=output+’\t’
if output[-1]!=\n': output=output+\n'
g.write(output)

print str(time.time()-t03)+' seconds to write text file.'
g.close()

print 'Ordered variable list:'; print
for i in keys__: print i

*******************************************************************************

# delay_parse_2

 Parse U.S. airport delay data, for WN entry model project.
 (version 2)

Updated 17 January 2009 with arrival delay data.

import cPickle,time,os,sys

module_dir=os.path.join('Project', 'code')
sys.path.insert(0,module_dir)

from safe_cPickle import *
from scipy import *

data_path='C:/Project/data/
filename='departure_delay_data_2001_2007.txt'

t0=time.time(); print; print 'Opening file: '+filename
f=open(data_path+filename,'r')
print 'Done. '+str(time.time()-t0)+' seconds to open file

agg_delay_dict={}
for i in f:
    a=i.split(\'\t\')
    if len(a[0])==3:
        if a[0] not in agg_delay_dict.keys():
            b=a[2:7]+[a[7].split(\'\n\')[0]]; c=[]
            for l in b: c.append(eval(l))
            agg_delay_dict[a[0]]=c

safe_cPickle_dump(data_path,\'dep_delay_dict\',agg_delay_dict)

filename='arrival_delay_data_2001_2007.txt'
t0=time.time(); print; print 'Opening file: '+filename
f=open(data_path+filename,'r')
print 'Done. '+str(time.time()-t0)+' seconds to open file'

agg_delay_dict={}
for i in f:
    a=i.split('\t')
    if len(a[0])==3:
        if a[0] not in agg_delay_dict.keys():
            b=a[2:7]+[a[7].split('n')[0]]; c=[]
            for l in b: c.append(eval(l))
            agg_delay_dict[a[0]]=c

safe_cPickle_dump(data_path,’arr_delay_dict’,agg_delay_dict)

*******************************************************************************
# lcc_parse

********

Parse U.S. airport data, for WN entry model project.
- JetBlue, Frontier, AirTran, Alaska.

import cPickle, time, os, sys

module_dir = os.path.join('Project', 'code')
sys.path.insert(0, module_dir)

from safe_cPickle import *
from scipy import *

data_path = 'C:/Project/data/'

filename = 'jetblue.txt'
t0 = time.time(); print; print 'Opening file: ' + filename
f = open(data_path + filename, 'r')
print 'Done. ' + str(time.time() - t0) + ' seconds to open file'

lcc_dict = {}
for i in f:
a = i.split('	'); b = []
if len(a[0]) == 3:
c = []
    #for j in a[1:]: b.append(float(j))
    for j in a[1:]: b.append((float(j) > 0) * 1)
c=[mean(b[1:5]),mean(b[5:9]),mean(b[9:13]),
mean(b[13:17]),mean(b[17:21]),mean(b[21:25])]

if a[0] not in lcc_dict.keys():
    #lcc_dict[a[0]]=c
    lcc_dict[a[0]]=b
print lcc_dict

safe_cPickle_dump(data_path,'jetblue_dict',lcc_dict)

filename='frontier.txt'
t0=time.time(); print; print 'Opening file: '+filename
f=open(data_path+filename,'r')
print 'Done. '+str(time.time()-t0)+' seconds to open file'
lcc_dict={} for i in f:
    a=i.split('	'); b=[]
    if len(a[0])==3:
        c=[]
        for j in a[1:]: b.append(float(j))
    c=[mean(b[1:5]),mean(b[5:9]),mean(b[9:13]),

mean(b[13:17]), mean(b[17:21]), mean(b[21:25])

if a[0] not in lcc_dict.keys():
    #lcc_dict[a[0]]=c
    lcc_dict[a[0]]=b

print lcc_dict

safe_cPickle_dump(data_path,’frontier_dict’,lcc_dict)

filename=’alaska.txt’
t0=time.time(); print; print ’Opening file: ’+filename
f=open(data_path+filename,’r’)
print ’Done. ’+str(time.time()-t0)+’ seconds to open file’

lcc_dict={} for i in f:
    a=i.split(’\t’); b=[]
    if len(a[0])==3:
        c=[]
        for j in a[1:]: b.append(float(j))

        c=[mean(b[1:5]), mean(b[5:9]), mean(b[9:13]),
            mean(b[13:17]), mean(b[17:21]), mean(b[21:25])]

        if a[0] not in lcc_dict.keys():
#lcc_dict[a[0]]=c
lcc_dict[a[0]]=b

print lcc_dict

safe_cPickle_dump(data_path,'alaska_dict',lcc_dict)

filename='airtran.txt'
t0=time.time(); print; print 'Opening file: '+filename
f=open(data_path+filename,'r')
print 'Done. '+str(time.time()-t0)+' seconds to open file'

lcc_dict={}
for i in f:
    a=i.split('	'); b=[]
    if len(a[0])==3:
        c=[]
        for j in a[1:]: b.append(float(j))
        c=[mean(b[1:6]),mean(b[5:9]),mean(b[9:13]),\
          mean(b[13:17]),mean(b[17:21]),mean(b[21:25])]
        if a[0] not in lcc_dict.keys():
            #lcc_dict[a[0]]=c
            lcc_dict[a[0]]=b

print lcc_dict
safe_cPickle_dump(data_path,'airtran_dict',lcc_dict)

*******************************************************************************

# service_since_parse

###

Parse WN airport service duration data, for WN entry model project.


###

import cPickle,time,os,sys

module_dir=os.path.join('Project','code')
sys.path.insert(0,module_dir)

from safe_cPickle import *
from scipy import *

data_path='C:/Project/data/'
filename='service_since.txt'
t0=time.time(); print; print 'Opening file: ' + filename
f=open(data_path+filename,'r')
print 'Done. ' + str(time.time() - t0) + ' seconds to open file'

since_dict={}
for i in f:
    a=i.split('	'); b=[]
    if len(a[0])==3:
        c=[]
        for j in a[1:]: b.append(float(j))
        if a[0] not in since_dict.keys():
            since_dict[a[0]]=b
print since_dict

safe_cPickle_dump(data_path,'service_since_dict',since_dict)
For helpful feedback and discussions, we are grateful to Roseline Bilina, Marie-Claude Beautes and Nathalie Lenoir. This paper was typed in MiKTeX and econometric results were derived using Eviews 6. The original .csv-datasets from the DOT, BTS, OMB and the U.S. Census Bureau were parsed into Eviews-acceptable formats using Python.
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