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Pricing Issues in the U.S. Airline Industry

by

Jesse Caldwell Weiher

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE DEGREE
DOCTOR OF PHILOSOPHY

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Abstract

Pricing Issues in the U.S. Airline Industry

by

Jesse Caldwell Weiher

This dissertation explores two important issues in the determination of U.S. airline fares: inflation and market power.

The first essay deals with the accurate measurement of inflation in the U.S. airline industry by calculating a quality adjusted price index for airfares. This calculation is achieved via an hedonic regression including relevant quality characteristics as well as time dummies. This new price index is compared with the index currently used by the BLS and reasons why the two indices diverge are discussed. Suggestions for a revision of the BLS practices are provided as well as data protocols for its implementation.

The second paper examines how market power affects the percentage that a carrier can charge above marginal cost. DOT's DBIA data set (1979 - 1992) and the DOT's form 41/T300 cost and production data are used to construct the percentage markup in price above marginal cost. This paper then examines how the percentage markup is affected by a number of market variables using reduced form methods. The results indicate that an increase in the Herfindahl Index, leads to increases in the Lerner index for markets with a dominant pair of firms. Airlines that have significant sales in other markets have a higher markup than other airlines and, finally, code-sharing has an insignificant, impact on a carriers' price-cost margins.

The third paper extends the analysis of the second paper by formally testing whether particular routes can be classified as competitive, Cournot oligopolistic, or
collusive. Again, using DOT's DB1A data set and DOT's form 41/T300 cost and production data set, a model of demand is jointly estimated with the first order conditions for profit maximization (which vary according to market structure). These models are then formally tested using a non-nested likelihood ratio test to determine which market structure dominates. The results indicate that of 3141 routes, 436 are collusive, 1852 are competitive and 838 are Cournot oligopolistic. Collusive routes are naturally monopolistic routes in the sense that carriers would be driven from the market by large economic losses were they forced to compete.
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To my wife Joie
and my parents Greg and Connie
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Part I

A Quality Adjusted Price Index For U.S. Airline Fares

1. Introduction

The Consumer Price Index (CPI) measures the price of a fixed market basket over time. Because the market basket is fixed the CPI does not allow for consumers to respond to price changes by substituting away from commodities with higher price increases towards commodities with lower price increases. Because price changes are considered only within outlets, the index does not allow for consumers to substitute away from higher priced outlets towards lower priced outlets\(^1\). Since the market basket is sparse in quality detail, the CPI also fails to consider the question of whether price increases are caused by unmeasured improvements in quality that increase the welfare of consumers\(^2\). The Boskin Commission, in 1996, concluded that changes in the Consumer Price Index overestimated the change in the Cost of Living by about 1.1 percent. This bias was attributed to the three factors

\(^1\)This introduction explains the motivations of the Boskin Commission. It is a Boskin Commission conclusion that there is an outlet substitution bias. One of the steps taken by the BLS, in order to address issues raised by the Boskin Commission, was to implement geometric means in the first aggregation step. This was introduced into the CPI in January of 1999 and implicitly allows for substitution among outlets.

\(^2\)There is a certain extent to which changes in quality which are observed by the BLS are dealt with. When one item in the market basket has an observable quality change, the "new" good is compared to the "old" good to determine if the quality change was large enough to render the goods incomparable. If they are comparable, the BLS continues sampling that item when tracking changes in the CPI. If they are incomparable, the BLS does not include the "new" good in the basket.
just mentioned: (i) having a fixed weight market basket neglects consumer substitution within commodities included in the basket (the substitution bias – measured at 0.4 percent); (ii) price collection within outlets neglects consumer substitution among outlets (outlet substitution bias – measured at 0.1 percent); and (iii) change in the quality of existing commodities and the introduction of new commodities are not controlled as well as they should be in the calculation of the CPI (quality change bias – measured at 0.6 percent). The commission concluded that increases in the cost of maintaining a constant standard of living were much less than indicated by the CPI. The impacts of this bias are far reaching. Many government expenditures, most notably Social Security are tied into the CPI. The bias has led the federal government to overcompensate individuals for the cost of living. It is reasonable to believe that such overcompensation has further accelerated inflation as more dollars in benefits chase less goods.

The commission generated many recommendations. Among them are: (i) use hedonic statistical methods to adjust for quality change; (ii) re-weight the consumption basket more frequently; (iii) increase the pace of sampling so that new goods can be accounted for more rapidly; (iv) study the individual components of the CPI to determine which components provide the most information about future movements in the index and which components have movements which are mostly irrelevant to movements in the total; (v) move toward the notion of a new "basket" every year; (vi) use new sources of data such as scanner data. This paper attempts to implement some of these recommendations and address bias
issues in the context of one specific component of the CPI – airline fares\(^3\). The consumer’s market basket of airline travel commodities is composed of a number of alternative city-pair routes. A quality-adjusted price index for airline fares is then calculated using a hedonic price regression which includes relevant quality characteristics as well as time dummies. These estimates are used to construct quality adjusted changes in price over time. The major data sets used are a one in ten sample of all tickets sold on a quarterly basis from the Department of Transportation’s (DOT) Origin and Destination Data Bank 1 A and carrier cost and production information from the DOT Form 41/T100.

The airline fares portion of the CPI is amenable to the Boskin Commission’s recommendations because a rich data set of ticket sales already exists. With other components, improved data collection may prove difficult because national level data collection requires cooperation that many industries won’t provide willingly. However, collection of airline sales data is already mandated by the Department of Transportation. Using the O&D database is especially useful in dealing with market basket issues. Because it consists of sales data, weights adjust as the quantity sold adjusts. When a new product is introduced (e.g. an airline adding a new route, the introduction of a business class fare, etc...) it shows up automatically in the data. Inter-regional comparisons can be made because the data collection techniques are the same across regions. There are still limitations: data are collected

---

\(^3\)This research was funded by a grant from the Bureau of Labor Statistics. Preliminary drafts were prepared for the BLS conference “Issues in Measuring Price Changes and Consumption,” June 5-8, 2000. Dennis Fixler and John Greenlees made a number of insightful and useful suggestions and criticisms that substantially improved the paper. I am also very thankful for the extensive and constructive comments by Cliff Winston and by Clint Oster. I also benefited from comments by Robert Gordon, Jack Triplett, and participants in the Brookings Institution’s “Workshop on Transportation Output and Productivity,” May 4, 2001. This chapter is based on an early draft of Good, Sickles, Weicher “A Hedonic Price Index for Airline Travel” 2000. The usual caveat applies.
quarterly rather than monthly, smaller airlines often under-report and some information about fare class is censored. However, the O&D set is still much better than existing sales data in other industries.

A number of studies have pursued these issues either in the context of airlines or in other transportation industries or sectors. Gordon and Griliches (1997), determine that the public transportation component of the index was biased by 2.66% from 1972-77, 4.6% from 1978-1982, and 0.00% from 1983-1996. The Laspeyres' index that the CPI uses is well known as an upper bound on a true COL index. Gordon and Griliches use a formulation that is more similar to a Paasche index. It is a long-standing theoretical result that the Paasche index is a lower bound on the true COL index. Consequently, Gordon and Griliches may have reported too much bias. A distinguishing feature of the work pursued below is the use of a hedonic regression that holds without considering weighting issues. Thus there is no reason to believe this index is biased in any direction.

Gordon and Griliches point out that some quality improvements are quite problematic because they represent an abatement of "bads" that were not considered in the CPI. For example, increases in the price of a flight due to increased safety measures may be a price change due to quality improvement. However, unless we also deal with the cost that was imposed due to increased risk of plane malfunction or terrorism, we will not be accurately reflecting the COL associated with it. It may be easily argued that patrons were better off before terrorism was ever a threat than after security measures were put in place. By not specifically accounting for the costs to increased risks, we will be overestimating the
effect of security on welfare and underestimating the cost of living. The security issue is not explicitly accounted for in our analysis, but this is an interesting point. One possible modeling approach to use in this regard that is not pursued is the directional distance function paradigm introduced by Fare et al. (1994) and recently utilized in the context of the impact of environmental "bads" on growth accounting by Boyd et al. (1999) and Jeon and Sickles (1999).

Society has benefited greatly due to airline deregulation. Caves, et al. (1987) show that deregulation has increased the passenger-mile productivity growth rate between 1.3 and 1.6 percent per year. Morrison and Winston (1995) show a number of important benefits accruing to consumers: 1) fares are on average 22 percent lower than if regulation was still in place; 2) an approximately $10.3 billion per year benefit resulting from the elimination of route restrictions and an increased use of hub-and-spoke networks; 3) while passengers often must take an indirect route associated with this hub-and-spoke network structure, they find the fraction of passengers with direct nonstop flights has increased; and 4) because of the increases in network size, passengers who do have to change planes rarely have to change airlines.

The benefit of hub-and-spoke systems is reduced due to longer travel time, both in-flight and waiting for flights. Ground time has increased by five minutes regardless of distance traveled. However, the cost of the increase in travel time ($2.8 billion per year) may be more than offset by the benefit of hub-and-spoke systems (Morrison and Winston, 1995).

While consumers have gained a great deal through deregulation, there are other pos-
sible innovations that benefit consumers indirectly, through lower effective costs passed through to consumers by way of airframe and engine innovations and the benefits of those innovations accruing to equipment manufacturers, airlines and passengers. A primary role of the National Aeronautics and Space Administration (NASA) in supporting civil aviation is to develop technologies that improve the overall performance of the integrated air transportation system, making air travel safer and more efficient, while contributing to the economic welfare of the United States. NASA conducts much of the basic and early applied research that creates the advanced technology introduced into the air transportation system. Through its technology research program, NASA aims to maintain and improve the leadership role in aviation technology and air transportation held by the United States for the past half century. To meet its objective of assisting the U.S. aviation industry with the technological challenges of the future, NASA identifies research areas that have the greatest potential for improving the operation of the air transportation system. By thoroughly understanding the economic impact of advanced technologies and by evaluating how those new technologies would be used within the integrated aviation system, NASA is able to provide some balance in its research program and helps speed the introduction of high-leverage technologies. The indirect impact of these governmental spillovers is reflected in part by lower marginal costs of providing quality adjusted city-pair service.

This paper is organized as follows. First is a discussion of hedonic regression theory. Next is a review of the seminal literature on the airline industry and the approaches these researchers have taken to resolving the problem of constructing a price for air travel. Then
is a discussion on the current methods employed by the BLS to calculate the consumer price index for airfares. After that is a review of the trends in a number of fare characteristics during the period of our study, 1979I-1992IV. Next is the construction of a new method that explicitly recognizes the role of quality characteristics on the consumer's valuation of airline service. This reduced form approach utilizes hedonic price index methods to weight down the actual reported output and thus weight up the effective price of airline service. The last section presents results and provides concluding remarks.


Hedonic price functions have been in the literature for almost 40 years starting with Griliches (1961) and have been widely used in the development of index numbers (e.g. automobiles, housing, computers). The automobile industry was one of the first industries to utilize hedonic methods (Griliches, 1961). The analysis of marginal prices of housing attributes through computation of hedonic indices began in the late 1960's (e.g. Ridker and Henning, 1967) and was extended in the 1970's\(^4\). Hedonic indices were applied to computers in the mid 1980's (e.g. Triplett, 1984). Other markets whose prices are being revalued using hedonic techniques include and the medical field (Primont and Kokoski, 1990; Trajtenberg, 1990) and college tuition (Schwartz and Scafidi, 2000). To our knowledge, our development a price index for airline fares via an hedonic price approach is new to the literature. What follows is a brief explanation of the theory behind the hedonic price relation and how this

\(^{4}\)Edel (1971); Rosen (1974); Oron, Pines and Sheshinsky (1974); Murray (1975, 1978a, 1978b); Kain and Quigley (1970, 1975); Triplett (1975); Walters (1975); World Bank (1975); Polinsky and Rubinfeld (1978); Harrison and Rubinfeld (1978); Goodman (1978); Freeman III (1979); Witte, Sumka and Erekson (1979)
relationship is used to specify and interpret the estimated hedonic airline price index\(^5\).

Assume the market provides us with observations on the vector \(F = (f_1, \ldots, f_p)\) of ticket attributes which completely describe the services provided by each ticket and the price, \(p\), of that ticket. Such attributes are: fare-class, number of segments, expected flight delays, type of food served, quality of flight attendants, et cetera. From observations on these tickets and their attributes, we can assume a single competitive market will yield the hedonic price relation

\[
p = \rho(F)
\]

which describes the relationship between the characteristics of ticket services and the prices they command. If we assume continuity, the marginal price of each attribute \(\partial \rho(F)/\partial f_i\) exists for any level of the other attributes.

Each ticket sold is a promise of a vector of attributes. For illustrative purposes, assume that only two attributes are relevant, \(f_1\) and \(f_2\). Perhaps \(f_1\) is a dummy variable that is 1 for a first class ticket and 0 otherwise and \(f_2\) is the number of in-between stops on the flight. The consumer faces the problem

\[
\max_{f_1, f_2, x} U(f_1, f_2, x)
\]

\[\exists \quad y = x + \rho(f_1, f_2)\]

which yields three demand equations for \(x\) (the composite, numeraire good), \(f_1\), and \(f_2\),

\(^5\)Much of this section borrows from Quigley (1982).
given exogenous prices and income. If we assume that the consumer buys one ticket, his utility function can be written as

\[ U = U(f_1, f_2, y - \rho(f_1, f_2)) \]

Holding the utility function at some arbitrary level, we have that for some given income \( y^0 \), the maximum amount \( B \) that can be offered for all bundles of attributes leaving the individual as well off as his/her optimal choice of bundle \( f_1^0, f_2^0 \) is such that

\[ u(f_1^0, f_2^0, y^0 - \rho(f_1^0, f_2^0)) = U^0 = u(f_1, f_2, y^0 - B) \]

This implies, together with the arbitrariness of the initial endowment, a bid relation function

\[ B = g(U, y, f_1, f_2) \]

which, for any endowment \( y^0 \) traces out a family of curves. Each curve indicates the bid for all combinations of ticket attributes at a given level of utility. The utility restrictions \( U_F > 0 \) and \( U_{FF} < 0 \) imply restrictions on the bid function \( B_F > 0 \) and \( B_{FF} < 0 \). Put in terms of the numeraire \( x \), the bid for a marginal increment in \( F \) is, in equilibrium, the marginal rate of substitution between \( F \) and \( x \).

\[ \frac{\partial B}{\partial f_1} = \frac{U_f}{U_x} \]
\[
\frac{\partial B}{\partial f_2} = \frac{U_{f_2}}{U_x}
\]

Since \(x\) is a numeraire good, the marginal rate of substitution is also the marginal willingness to pay. Rosen (1974) notes that \(\partial B/\partial f_i\) is the Hicksian demand curve for \(f_i\).

In a general framework, market data provides us with observations about two properties:

- At the equilibrium chosen by each consumer, the value of the bid curve must equal the value of the hedonic price relation.

\[p = \rho(f_1, \ldots, f_n) = B = g(U, y, f_1, \ldots, f_n)\]

- For each individual, the partial derivative of the bid curve (and hence the marginal rates of substitution) must equal the partial derivative of the hedonic price function.

\[
\begin{align*}
\frac{\partial p}{\partial f_1} &= g_1(f_1, \ldots, f_n, Z_1) = \frac{\partial B}{\partial f_1} = \frac{U_{f_1}}{U_x} \\
& \vdots \\
\frac{\partial p}{\partial f_n} &= g_n(f_1, \ldots, f_n, Z_n) = \frac{\partial B}{\partial f_n} = \frac{U_{f_n}}{U_x}
\end{align*}
\]

where \(Z_1, \ldots, Z_n\) are exogenous shift variables.

Under the assumption that the hedonic price relation is linear, we have the equations.

\[p = \beta_1 f_1 + \cdots + \beta_n f_n = \rho(f_1, \ldots, f_n)\]
\[
\frac{\partial p}{\partial f_1} = \beta_1 \\
\vdots \\
\frac{\partial p}{\partial f_n} = \beta_n
\]

which forms an identifiable model (trivially) and can be estimated using standard techniques. In this case, a hedonic regression yields parameter estimates that can be interpreted as the marginal rates of substitution between the attribute and the numeraire commodity — or equivalently, the marginal willingness to pay. A linear model seems too primitive, especially because it forces an assumption of constant marginal rates of substitution and, hence, linear indifference curves.

Under the assumption that the hedonic price relation is log-linear, we have the equations.

\[
\ln p = \beta_1 \ln f_1 + \cdots + \beta_n \ln f_n = \ln \rho (f_1, \ldots, f_n)
\]
\[
\frac{\partial \ln p}{\partial \ln f_1} = \beta_1 \\
\vdots \\
\frac{\partial \ln p}{\partial \ln f_n} = \beta_n
\]

which are identifiable (trivially) and can be estimated using standard techniques. The parameter estimates can be interpreted as the percentage change in willingness-to-pay due to a percentage change the attribute \(f_i\) (or the inverse of the price elasticity of demand for attribute \(f_i\)). If an attribute is "good" the sign of the parameter associated with it
should be positive and vice versa. This paper estimates a hedonic price relation that is log-linear. The attributes considered in the regression are: food, number of departures, number of segments (two-segment dummy for one-way tickets, three and four segment dummy for two-way tickets), and the number of interline segments. These attributes are discussed in detail in section 5. Time dummies are included in the regression in order to both deal with heterogeneity over time and to allow a direct approach for constructing a price index.\textsuperscript{6}

3. Pricing Issues in The Airline Industry

Morrison and Winston (1995) calculate marginal valuations of quality characteristics via an airline choice model. The marginal value of an additional mile for traveler’s who have accumulated 3,501 to 15,000 miles is 13 cents, and for traveler’s who have accumulated 15,001 to 80,000 miles is 21.5 cents. They estimate the cost of restrictions on a discount flight via a binary, probit model of choice between unrestricted vs. restricted fairs. Initial estimates show no significant cost on leisure travel. However, the business traveller did incur some significant costs. Particularly, the Saturday night restriction added $219 dollars of disutility. Advanced reservation requirements imposed a cost of $3.68 a day. Overall, business travelers (via a compensated variation method) were willing to pay $87 dollars per trip to avoid restrictions, a substantial portion of which was due to the Saturday night stay ($67). They also estimate a fare equation for each carrier to investigate whether multimarket contact has an affect on prices. Airlines who compete with each other in many

\textsuperscript{6}Several hedonic regressions have been done using time dummies. For a discussion on the relative benefits and costs of such an approach see Silver (1999).
markets may have a stronger incentive to engage in tacit collusion (and avoid fare wars) than airlines that compete only in a few markets. They find that multimarket contact does have an effect on fares in the industry, but that these changes have a highly cyclical nature. In general, when the economy is growing rapidly, fares where there is multimarket contact are higher than fares where there is no contact. However, there are recessionary periods where the opposite effect occurs. Multimarket contact might be considered a benefit to consumers because it allows for the possibility of greater competition. Even in the presence of collusion on prices, airlines might still compete along quality dimensions (an e.g. is Continental competing with United in D.C. area markets by allowing for more carry-on luggage space. United tried to implement a carry-on size limit and Continental is currently in litigation). To the extent that consumers might look to multimarket contact as a signal of higher quality and/or lower fares, including this into further analysis seems prudent.

The Boskin Commission notes that the CPI is a modified Laspeyres index in that it uses a market basket of goods and services which is based on consumer expenditure patterns at a point in the past (the base period). Many have argued that the CPI should be more like a Cost-of-Living (COL) index. A true COL index reports the minimum cost of purchasing a market basket today that produces the same level of satisfaction as the market basket purchased in the base period. This allows for consumers to substitute within the market basket. Because the CPI holds living standards constant and fixes the market basket, whereas the COL holds the standard of living constant and allows for quantities to change, the CPI forms an upper bound on the COL. Most quality adjustments made by the CPI use
an imputation procedure that estimates the price change of a new product (or old product with new quality feature) by the average price changes of similar products currently in the market. This assumes that the underlying price change of the service not currently available would have been the same as the price changes of services currently in the market. However, if this is not the case, then the imputation procedure would miss important price changes. Armknecht and Ginsburg (1992) illustrate this problem in the context of airline fares:

"...As an example of this situation consider airfares. The airlines at one point in time introduced a new set of discount airfares to replace supersaver fares. Originally, supersaver fares required a 30-day prepayment to obtain the reduced fare. The new discount fares introduced a lower price structure than the supersavers and required the 30-day prepayment. However, along with the lower fares came a 50-percent cancellation penalty, a quality difference between the fares that may/should make them noncomparable. If no other airline price changes occurred during this month, the exclusion of the discount quotes would result in an imputed price change of zero because all other airline fares (coach and first-class) remained the same. The index, therefore, misses any possible price change occurring with the introduction of the lower discount fares under current procedures (this problem would exist even if other fares changed but at a different rate)."

Armknecht and Ginsburg (1992) offer hedonic regressions as another way to address these quality changes. The general form of the model is log linear which provides a direct interpretation of parameter estimates on quality characteristics as a percentage change in price due to a unit change in the characteristic. These hedonic models not only help in esti-
mating the quality difference resulting from a change in a characteristic; they also enhance the analyst's information on the quality composition of services offered. Specifically, the models can identify those quality characteristics that provide the largest impacts on price. Armknecht and Ginsburg suggest two important benefits related to these insights. First, analysts can create a formal statistical test for whether changes in a quality characteristic render the old and new services incomparable. Second, the factors that provide the most impact on price can be used to redesign collection documents used by the CPI. By ordering the quality characteristics according to importance, the field staff can pick the most appropriate substitute by the most important characteristics according to the appropriate order.

Dean Baker's (1998) criticism of the Boskin Commission's report is also worth reviewing. Baker notes that there are at least six distinct problems that can be identified in the commission's estimates of quality and new goods bias. They are:

"...1. Many of the estimates depend exclusively on introspection - thought experiments in which the commission members speculate on the amount of bias in the index. The commissioners use introspection to make estimates of bias that cover 58.33% of the index and account for 0.171 of the 0.612-percentage-point estimate of quality and new goods bias.

2. In a set of estimates, the commission has misinterpreted the findings of earlier research. This problem arises in estimates of bias in items that make up 10.37% of the index and account for 0.242 percentage points of the commission's estimate of bias.

3. In some estimates, The commission has made dubious extrapolations from research. Es-
timates that cover 6.47% of the index and account for 0.038 percentage points of bias fall into this category.

4. In another set of estimates, BLS has implemented a procedural change that has not been taken into account. These estimates cover 5.73% of the index and account for 0.172 percentage points of bias.

5. In the commission's treatment of personal financial services, a category that covers 0.4% of the index and accounts for 0.009 percentage points of bias, the source of bias identified (if accurate) should apply to the measure of personal income in the national income and product accounts, not to the consumer price index.

6. One of the commission's estimates (for nonprescription drugs and medical supplies) has no support whatsoever. This estimate covers 0.39% of the CPI and accounts for 0.004 percentage points of bias...."

Related to the Boskin Commission's substitution bias and outlet substitution bias is another type of substitution bias that few have discussed. This bias results from short term, intertemporal substitution. The CPI samples only prices and uses the Consumer Expenditure Survey to attach sales weights to the prices that are sampled. This implies that price variations do not change quantities purchased. There is a chance that a particular outlet accidentally sets a price that is very high and elicits few sales. The outlet might notice the mistake quickly and lower price accordingly. However, if the CPI samples the high price, the CPI measures a price increase due to a temporary mistake that affected few people, if anyone at all.
For illustration, consider this example: An airline sets a high price on a first class, unrestricted ticket from Houston-Hobby (HOU) to Baltimore Washington (BWI) because of an error in estimating demand. The price is so high that no purchases are made. Two days later, the airline lowers its price and registers sales. The CPI, using the SABRE reservation system, samples the high price. Perhaps it also samples the lower price. However, the average price during that month is much higher than it would have been had the CPI ignored the higher price which had no sales. As a result, there is an upward bias in price change from the previous month to the current month due to measuring an advertised price that elicited no purchases. If the airline did not make the same pricing mistake in the next month, the price level that month would be correct. However, the price change from the first month to the second month would be negative when it should have been zero (a downward bias).

This would be an example of "substitution" bias if people responded to the higher price by purchasing a ticket from the same airline for the same route but with a different fare class. It would be outlet substitution bias if people responded by purchasing a ticket sold by another airline. However, if some people responded simply by waiting for two or more days and purchasing the same ticket at the lower price, then no bias previously talked about would apply. This type of intertemporal substitution would also occur if people responded to upcoming sales by holding off on purchases until the sale took place. Since many sales are advertised before hand, one might conclude prices preceding sales events will correspond to fewer purchases. By treating each price sampled for the same service in the same period as
equal, these substitutions are missed. This would not be a problem if BLS sampled prices and sales rather than just prices.

4. The Current BLS Approach for Constructing a CPI for Airfares

The airline fares index is the largest component of the public transportation index. The public transportation index has a 1.338 weight in the U.S. city average for the Consumer Price Index, of which airline fares contribute .814 (or 61%) to that index.

All regularly scheduled commercial airline trips departing from airports in the 87 cities in the CPI are eligible for use in the index. Several of these cities do not have a qualifying airport. In this case, the nearest city with a qualifying airport is designated as the city of departure.

The BLS selects approximately 850 observations for its airline fares index. The sample is selected using the qualifying airports as the points of origin. Reflecting the pattern of trips in DB1A, the CPI sample of airline trips selected from DB1A currently consists of 94% discount fares, 4% full coach and 2% first class.

For discount fares, there are several fares to choose from. 50% of all discount fares are the lowest available fares. The rest are quotes for specifically selected discount fares other than the lowest available fare. The SABRE reservation system is used to follow prices of airline fares in the CPI. This is the same system used by much of the travel industry.

When an airline discontinues a discount fare that is being priced, the BLS substitutes the closest available alternative. However, applicable restrictions may change, thus changing
the "quality" of the flight. BLS estimates the value of this change. If the value is high, the two fares will not be compared. Usually, however, the change is not large and the fares are compared and reflected in the CPI.

4.1. An Algorithm Explaining How the BLS Calculates the Air Fares Portion of the CPI

1. The market basket is a set of origin-destination-fare class triples. Conduct random price sampling for all items in this basket.

2. For a particular item, \( i \), in the basket, take the ratio of current price to lagged price,
\[
\frac{p_{i,t}}{p_{i,t-1}}.
\]

3. Implement one of the steps below

1. If sampling is done after January 1999, raise this ratio to a power that represents the share of that item in the relevant Price Sampling Unit (PSU), \( j \), in the relevant Consumer Expenditure Survey (CES), \( r_{i,t}^a = \left( \frac{p_{i,t}}{p_{i,t-1}} \right)^{s_{i,j}} \).

2. If sampling is done before January 1999, multiply this ratio by a number that represents the share of that item in the relevant Price Sampling Unit (PSU), \( j \), in the relevant Consumer Expenditure Survey (CES), \( r_{i,t}^b = \left( \frac{p_{i,t}}{p_{i,t-1}} \right) \cdot s_{i,j} \).

\( s_{i,j} \) is the "area weight" for good \( i \) in the basket and PSU \( j \).

4. Implement one of the steps below
1. If part (a) of step 3 was used – Within a particular PSU, \( j \), take the product of the last number to get the "relative", \( R_{j,t}^a = \prod_i r_{i,t}^a \). This is the geometric mean of the ratio within a given PSU using base period weight provided by the CES.

2. If part (b) of step 3 was used – Within a particular PSU, \( j \), take the sum of the last number to get the "relative", \( R_{j,t}^b = \sum_i r_{i,t}^b \). This is the arithmetic mean of the ratio within a given PSU using base period weight provided by the CES.

5. Multiply the "relative" in each PSU by a number that represents the share, \( S_j \), of all sales in the PSU relative to the entire US. Sum these shares up to get the aggregate weight, \( W_t^k = \sum_j R_{j,t}^k S_j \). Where \( k = a \) or \( b \) depending on whether the date is before or after January 1999. \( S_j \) is the "US weight" for PSU \( j \).

6. Arbitrarily set the index in the base period at 100. The index in the next period is \( 100 \cdot W_{b+1}^k \) where a \( b \) in the subscript represents the base period. The index in the previous period is \( 100/W_b^k \). In general, the index for the \( l \)th period ahead of the base period is \( 100 \cdot \prod_{n=b+1}^{b+l} W_n^k \) while the index for the \( l \)th period before the base period is \( 100/\prod_{n=b-l}^{b} W_n^k \).

### 4.2. Issues in Implementing CPI Methodology

Several issues presented themselves while attempting to replicate the airfare index using CPI methodology. These issues are described below. The results of CPI replications are discussed in section 6.
4.2.1. To Use Geometric or Arithmetic Means?

CPI methodology for the time periods relevant to the data set (1979-1992) required arithmetic means for all aggregation steps. In January of 1999 the CPI changed this practice and implemented geometric means in the first aggregation step. It was thought that geometric means would help to correct any upward bias in the CPI (geometric means are always bounded from above by arithmetic means).

Since the purpose of this paper is to ascertain whether the airline fares portion of the CPI was biased, two potential questions posed themselves: (1) Was the airline fares portion of the CPI biased during the period from 1979 to 1992? (2) If there was a bias would new CPI methodology have led to a reduction in that bias?

To answer these questions, it was decided to construct two price indices. The first would replicate the methodology used while the data set was generated. The second would replicate methodology after improvements in methodology had been made. The first price index would answer whether there was a bias while the second price index would answer whether that bias (if present) would have been reduced by new methodology.

4.2.2. Issues with the market basket

The only market basket available for this paper was the one currently used to calculate the airline fares portion of the CPI. This basket was formed in 1998 and represented fair class purchases as they were made in the late 90's. This includes deeply discounted fares with corresponding restrictions that were not available in many of the years that the data set
covers. Market baskets for earlier years were unable to be obtained because the BLS does not save market baskets once they have been changed.

Ideally, the market baskets used during the interval covered in the DB1A data set would be used. This was the way the BLS calculated the airline fares portion of the CPI. These market baskets could not be obtained, however. Two choices presented themselves. (1) Use the market basket from 1998 knowing that the basket has changed over time. (2) Use fare-classes as they are represented in each quarter of the DB1A data set. The first approach uses an incorrect market basket but keeps a constant fare-class mix. The second approach uses fare-class mixes that are closer to what would have been in older market baskets but loses some of the fixed-basket qualities that the CPI has always had.

A decision was made to drop fare-class from the market basket while still using the origin-destination pairs\(^7\). All fare-classes would be sampled from the current period in the DB1A data set. The origin-destination pairs were still maintained. This seemed a closer approximation (to what CPI methodology would have been) than using a fixed-basket with an obviously incorrect fare-class mixture.

4.2.3. Issues with Weights

Another problem arose when considering weights. The only CES weights available for this paper were the ones currently used to calculate the airline fares portion of the CPI. These weights were formed in 1998 and represented ticket purchases as they were made in the late

\(^7\)A first attempt was made using the fare-classes in the market basket. The resulting series deviated significantly from actual BLS numbers. This was seen as a sign that the new market basket was "too" different (from what old market baskets would have been) to be useful.
90's. Weights for earlier years could not be obtained because the BLS does not save weights once they have been changed.

As with the issue of market basket, the ideal scenario was not available. Two choices again presented themselves. (1) Use the weights given even though they are incorrect. (2) Use sales weights from each period of the DB1A data set. By choosing to not use a market basket with a fixed fare-class mix, using the area weights (those used in step 3 of the algorithm) from 1998 became impossible. It also seems that weights from the period under consideration would be a better approximation to CPI methodology than fixed weights from a period in the distant future.

As for the U.S. weights (those used in step 5 of the algorithm), no alternative (other than using 1998 weights) presented itself. The U.S. weights represent all sales in an index PSU relative to the entire US. These numbers were generated using population data which are not included in DB1A. Since the DB1A data set cannot give this information it was decided to continue to use the 1998 weights.

5. Issues in Computing a New Quality Adjusted Airfare Price Index

The CPI is best computed when the product under consideration is a simple homogeneous commodity. This does not describe the air transport industry because air travel takes place between many different origins and destinations over alternative paths and with differing levels of service. In this section several of the important dimensions of air travel are discussed.

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\(^8\) Again, a first attempt at replicating the BLS series with the newer weights was made. The resulting series was very different from actual BLS numbers - indicating that the newer weights were "too" different (from what older weights would have been) to be useful.
as well as how they affect the price of travel through changes in quality. The ability of this paper to deal with these issues in the short run is limited by both time and appropriate data. Consequently, a longer run research agenda along with potential data sources is outlined. These issues fall into seven broad quality categories: Network configuration, flight convenience, passenger amenity, airport and flight delay, ticket restrictions, yield management, and zero coupon tickets. In many cases the choice of study period, from 1979 through 1992 is both practical, interesting and terribly restrictive. It is interesting because many fare innovations and service quality changes occurred during this time period. It is restrictive because many of the data sets which would be useful to identify service quality changes do not span this study period. It is practical because many of the data sets which are required to conduct this analysis have been previously obtained, and updating these data to more current time periods are prohibitively expensive.

5.1. Network Configuration

Much has been made out of changes in airline networks by increased use of hub-and-spoke type networks. Airlines find these network configurations useful because they allow for higher passenger densities on individual routes. For example, in a simple network involving 5 cities (one centrally located), these cities can be connected with at most one change of plane service with as few as 4 flights. Connecting these cities together with a network where there is nonstop service would require 20 flights.

Indirect routing of passengers clearly benefits the airlines because they can provide travel to passengers with fewer flights, potentially taking advantage of economies of equipment
size (larger aircraft tend to have lower costs per passenger mile) and higher load factors (filling otherwise empty seats on an aircraft cost the airline very little).

In general, indirect routing of passengers is something that passengers would like to avoid. Their time is valuable. Indirectly routing a passenger, especially when it involves changes of planes is definitely less desirable than a direct flight. There are some exceptions to this. Indirectly routed passengers often will accrue more frequent flyer miles than a directly routed passenger.

Other characteristics involving network configuration for passengers include origin-destination combinations for which no airline offers service. These situations require that a passenger take part of their trip on one airline and the remainder on at least one other airline. This interlining is generally considered a lower quality of service for the passenger than if their entire trip was on a single airline. Changing airlines is perceived to increase the likelihood that baggage will be mishandled or misdirected, it also typically increases the distance between gates at the connecting airport. The passenger also perceives reduced coordination between the carrier on the first segment and the second.

In this model these different network characteristics are measured at the individual ticket level. The Department of Transportation's Origin/Destination database DB1A provides a 10% sample of all domestic tickets and allows identification of many of the characteristics of the trip. Most fundamentally, the origin of a trip is identified, and the ultimate destination as indicated by a trip break. Approximately 95% of trips are either one way or round trip (depending on the year) with a small number of multibreak tickets involving as many as 23
Figure 5.1: Number of Ways

different flights. More complex routings tend to be slightly more prevalent in later years than in earlier ones. In order to gain an understanding of the bulk of trips attention is limited to either one way or round trip tickets. The changing pattern of these tickets is described in Figure 5.1

Typically, two thirds of the tickets are round trip. This declined about 10 percent in the mid 1980s but returned to its previous levels by the end of the decade. These ticket types are considered to be different enough to demand a separate analysis for each type.

The ticket itinerary allows one to measure the number of airlines taking part in the trip as well as a count of the number of times the airline changes (interlines). For one way
Figure 5.2: One Way Interlines

tickets, the number of airlines (NALINS) and the number of interlines (INTER) are nearly the same. 28% of the tickets had more than one airline and the average number of interlines was 28% in 1979-1. By 1992-4 only 4% had passengers interlined. These patterns can be seen in Figure 5.2.

The pattern for round trip tickets is quite similar. In 1979-1 nearly half of the round trip itineraries involved more than one airline. Some of these involved more than one interline as an itinerary started with one carrier, switched to a second, then went back to the first carrier on the return (Figure 5.3).

For both one way and round trip tickets, the data suggest that there has been a large
improvement in the quality of service over the study period. The information from the
Origin and Destination data also allow for the measurement of the number of segments in
a ticket. While these are not considered as bad, from the passengers perspective, as an
interline, a new segment does require that a change of plane occur. These are summarized
by the variable CSEGS for one way and round trip tickets in Figure 5.4.

The minimum number of segments for a one way ticket is one. Figure 5.4 shows that
approximately half of the one way itineraries involved an additional segment in 1979-1. But,
by 1984, this number fell to 25%. Again, this demonstrates an improvement in the quality
of airline service as fewer plane changes are required. A very different pattern emerges for
round trip tickets which have a minimum of two segments. In 1979-1 the average number of segments was 2.8, this increased somewhat to 3.05 by 1992-4 indicating a reduction in the quality of service. At 3.0 it suggests that approximately half of the itineraries involved a change of planes on the outbound and inbound portions of the trip. The rationale behind the difference in the one way and round trip ticket patterns is not clear. It may suggest a correlation between one way and full fare tickets which have a higher quality of demanded service for the large premium in price. On the other hand, while the presumption behind round trip tickets is that they describe the full trip, this is not the case for one way tickets since the passenger will require, at the minimum, an additional ticket for the return flight.
Consequently the presumption that a full fare ticket involves the ultimate destination seems less well founded.

An additional way to characterize the network quality associated with a particular ticket is to examine its CIRCUITY. An indirect routing forces the passenger to travel more miles than they would prefer to travel. The CIRCUITY of an itinerary is measured by adding up the miles associated with each ticket segment (measured by the great circle distances which corrects for the curvature of the earth) and dividing it by the number of miles associated with a direct routing of the passenger (again measured with great circle distances). Both distance measures ignore the additional travel associated with take offs and landings. The following figure suggests that the patters of circuity are similar to those for CSEGS. Both indicate a small amount of circuity associated with trips, averaging 5% for both one way and round trip tickets. This is generally declining slightly for one way tickets and increasing slightly for round trip tickets. This suggests that while changes of planes may be necessary, they occur at an airport which is in the same direction as a direct routing would take the traveler (Figure 5.5).

The circuity measure does not, unfortunately, allow one to capture indirect routing which does not involve a change of planes since there is no information on the routing of flights or flight numbers in the OD data. Additional sources of information which may shed some light on how this quality has changed over time are being explored by the author, although this type of indirect routing cannot be used at the ticket level. The final aspect of network configuration deals with service to small communities. These are described below.
under the heading of flight frequency.

Simply put, passengers desire the simplest ticket: a direct nonstop flight to their destination and a similar flight on their return. Itineraries which depart from this simple ticket will typically affect more than one measure. For example, if the passenger flies through the airline’s hub and must change planes, the routing is usually not as direct (more than the minimum of miles were flown) which affects the CIRCUITY measure and CSEGS increases by one as well. If the passenger must complete the second leg of the journey on a different airline then both NALINS and INTER increase by one. While multi-collinearity is not itself as critical an issue as it might be under some circumstances (there are nearly 300 million
observations these separate effects can be identified with some precision), the coefficients would have peculiar, and less interpretable meanings because of what they would imply was being held fixed. For example, it is not clear what it means to increase NALINS while holding INTER fixed. Further, some of the preliminary results suggest that including the full suite of these variables does little to explain variation in price and will subsequently describe little quality adjustment for the hedonic price index.

The choice of which of these network variables to include is motivated by two factors: which appear to be most consistently measured in the data source, and which appear to most directly affect consumers. It is the authors belief that consumers care more about the increased stress on interlines than they do about having an additional airline provide service. Our motivation to use CSEGS rather than CIRCUITY is motivated because a change of planes involves a more uncontrollable, unpredictable situation to the consumer than does additional in-air time. Further, because one must accept the true origin-destination for the DB1A tickets as those identified by DOT’s algorithm, we believe that there is less mismeasurement for CSEGS than there is for CIRCUITY.

5.2. Flight convenience and availability

Passengers typically have clear preferences regarding the time of travel and location of departure. This may involve choosing the time of departure or the time of arrival at the destination or the airports used. The willingness to accept other flight times or locations vary a great deal with trip purpose. Ideally, one would measure when and where the passenger wanted to leave and when and where they actually left. This is not possible.
Instead this aspect is proxied by including a measure of service quality that deals with the availability of a seat at the time and location desired: the number of departures at the airport of origin, DEPART.

One of the effects of the deregulation was to free airlines from prior service to small cities requirements. That is, during the regulated era there was exit regulation which was every bit as restrictive as entry regulation. When an airline reduces the service they have to small communities the passengers who would use those services must go elsewhere, typically, driving to an airport farther from where they live. Passengers value service to small airports because it lowers their complementary travel costs, and they would be willing to pay more for it. The departures variable is measured as total scheduled departures from DOT'S Airport Activity Statistics. Form 41 Schedule T3 to describe airport size. The patterns for different size airports suggest a major shift in the way airlines have changed their patterns of service to different communities.

Figure 5.6 describes the average daily departures for large, medium, small and very small airports. Large airports are defined as being in the top 20 airports for total departures summed between 1979 and 1992. For this group, the number of departures increased by 34% over this period. A group of medium sized airports are identified as those ranked between 100 and 120 in total departures over the 14 year period. There was a 20% increase in the number of departures for these medium sized airports. Small airports are defined as those ranked between 300 and 320 in terms of total departures. For this group, too, departures increased by approximately 20%. For a group of very small airports, those
Figure 5.6: Departures by Airport Size
ranked between 400 and 420, the departures declined by 80% over the 14 year period. This clearly illustrates the shift away from very small cities. From the airline's perspective this shift is a rational move. Offering service to these small cities is a very expensive proposition when few enplanements can be expected. From the passenger's perspective offering service to small communities is a desirable thing because it means that they will not have to travel to some other airport. For this study, departures from small communities indicate high service quality and a corresponding willingness of passengers to pay higher prices than they would be willing to pay at the closest medium or large airport.

Additionally, larger airports are more likely to be associated with higher congestion and an increased likelihood of flight delay. For both of these reasons, one would anticipate that airport size is negatively related to the quality of service and price.

5.3. Passenger amenity

When airline fares were regulated carriers could not use price to attract customers. Instead they used service quality which was unregulated. One of the major aspects to this service quality was flight frequency. Other dimensions include passenger amenity. This paper describes three dimensions to passenger amenity: space, food, and class of service although, because of a lack of appropriate data, only passenger food and a first class dummy are explicitly included in the initial model.

There are several potential ways to describe space based on physical measurements of the space per passenger or the psychological measurements of the perceived space per passenger. This paper uses the former and employs recently obtained data which describes
the cabin configuration and operator of individual aircraft in the world fleet since 1970. Most importantly this includes the number of seats and the aircraft type. Using information from the manufacturer about the amount of cabin volume on an aircraft and dividing this by the number of seats, the perceived space per passenger can be constructed. Entries are included in the database if the aircraft is reconfigured. However, because there is no way to link this measurement to the ticket level data (DB1A does not list the flight number or the type of plane flown), it is not included into the model.

Food has been a traditional aspect of service quality. When prices were regulated along with flight frequency, food was a major aspect of service competition. It seems clear that the more that an airline spends on food the higher the quality of service received by consumers. Information about a carriers food expenditures is obtained from Form 41 Schedule P6 and divided by the number of enplanements during that quarter to get food expenditures per enplanement. The average across all carriers by quarter is summarized in Figure 5.7.

The data suggest that there has been a gradual increase in food expenditures per passenger (variable Food2). Even when one controls for inflation in food prices (we use the producer price index for all processed foods to get variable Adjusted in Figure 5.7), after a slight decline, expenditures per passenger have increased by about 25%. If the food expenditures was simply passed through, it would indicate that about 3% of the price of travel, on average, could be attributed to food expense.

This figure masks the large variability that occurs across airlines. Some carriers, for example Pan Am, spent nearly twenty dollars per passenger on average prior to their merger
with National. Low cost carriers like Southwest Airlines spend almost nothing on passenger food. Nominal food expenditures per passenger are incorporated in this study.

A third aspect to passenger amenity is the explicit class of service: first class, business or coach. This should be very correlated with the specific amenities for both food and space received by a passenger. Figure 5.8 characterizes the fraction of first class tickets for round trip itineraries. It tracks the gradual decline in the use of first class.
Figure 5.8: Fraction of Round Trips that are First Class
5.4. Airport Congestion and flight delay

Flight delays are an important aspect of service quality. Passengers have a great deal of anxiety over missed connections and delayed or canceled flights. The Department of Transportation currently maintains detailed flight delay information on an individual flight basis. This data was not incorporated into the study for four reasons: first, it is available only starting in September of 1987, more than half way through the study period. Second, it is very expensive. This data would cost $10,800 for the six years in the study period and over $20,000 for data through 1998. Third, the delay data essentially has changing meaning over time. Airlines have recognized that passengers use delay information in the selection of flights. They have countered this by increasing the scheduled duration of the flight to increase on-time performance. Fourth, a paramount objective in the nation's air traffic system is safety. Flight delays are not included in the aggregate delay statistics for weather or equipment safety reasons to eliminate any incentive to improve apparent service quality at the expense of safety. Reservations systems have countered this by incorporating both the scheduled duration of the flight and delay information into their prioritization of flights for display. The good features of this data are that it provides very detailed information on actual flight operations. It provides information on taxi time both on takeoff and departure, and time in flight along with scheduled departure and arrival times. This allows airport congestion as well as flight specific delay information. On the other hand, while not impossible, connecting this information to the origin and destination ticket information is far from a trivial exercise. It would require getting an airline specific aggregation of flight
segments to aggregate up over the quarter all of those flights which provided direct or multi-stop service on a particular coupon segment.

5.5. Ticket restrictions

A major feature of airline fare structures is ticket restrictions. These either increase the risk of travel for consumers (non-refundability) or provide the airlines with improved predictability about demand (advanced booking) and enhance their ability to provide price discrimination information separating price sensitive consumers from business travelers with more inelastic demands (Saturday night stay-overs). The major liability of our use of DOT's DB1A as the primary source of ticket information is that it includes very incomplete information on ticket restrictions. There is typically a lag between fare type innovations and the way they are reported in DB1A. This makes it difficult to identify a consistent set of conditions under which service was accepted. This limitation has been less problematic in subsequent years to include some information about the ticket fare code (K, Q, etc.). All that can be consistently identified from the fare class code is that some kind of discounting was used on a particular ticket. These are summarized in Figure 5.9 which describes the fraction of all tickets which were discounted coach tickets for one way and round trip travel.

The data shows a steady increase in both one way and round trip tickets that are discounted coach. For round trip tickets, this involved only 30% of tickets being discounted coach in 1979-1 increasing to nearly 90% of the round trip tickets being discounted coach by 1992-4. The three large declines in 1988 and 1989 are quarters in which virtually all fare
Figure 5.9: Fraction Of Itineraries that are Discounted Coach
information was not recorded by DOT. As mentioned previously, inclusion of these quarters would require that a model be used to estimate the fare class based on other available variables.

5.6. Other Factors

5.6.1. Route Specific factors

There are clearly other variables which many have attempted to incorporate into modeling the demand side of long distance travel. These include factors which are weather related, such as mean temperature difference, in an attempt to capture vacation travel in the winter months. Others have included variables which attempt to capture the demand for business travel such as the number of white collar jobs in an area. In this paper it is assumed that these factors are either very slow to change or that they are strongly correlated with other factors in our model (for example, white collar jobs are likely correlated with per capita income). These slowly moving factors are captured with fixed route specific effects which describe the origin-destination pair. In the model this amounts to approximately 115,000 route effects for the one way models and 134,000 for the round trip models.

5.6.2. Yield management

There is a great deal of competitiveness in the published fares. It is not at all uncommon for different airlines providing service on the same route to offer similar fare classes (sets of fare restrictions) at an identical price. But their fare structures may be radically different because of yield management practices. Many of these published fares may simply be
unavailable. They will certainly occupy different fractions of the seats sold on a particular flight or in a particular market. It would be inappropriate to model the situation as though the fare described the price at which people were just willing to accept the particular restriction. Because of this lack of availability of different fares consumers typically will meet higher sets of fare restrictions than those actually required by their ticket. For example, a consumer may meet the 30 day book in advance, no refund, Saturday night stay restrictions, but because this fare is sold out, they may accept a 14 day book in advance, no refund, Saturday night stay fare. This suggests one of the major advantages in our use of the Origin Destination data as the source of fare information when compared to BLS’s use of SABRE.

5.6.3. Zero coupon tickets

Frequent flyer miles were introduced in the mid 1980s by perhaps the leader of brutal competition, Robert Crandall at American Airlines. The purpose behind this technique was to increase customer loyalty to a particular airline by offering them free travel at a later date. This technique has proven so successful that it has proliferated to other industries, even grocery stores offers discounts for frequent shoppers. The CPI currently totally ignores zero coupon tickets. The pattern of these tickets over time is described in Figure 5.10 for one way and round trip travel. For both round trip and one way travel there is a spike in 1987 associated with the introduction of these tickets to about 10 percent of both one and round trip travel. By 1988, these decline to about 5% of round trip travel and about 4% of one way trips.

The use of zero coupon tickets is not straightforward. They are determined by a mix of
Figure 5.10: Fraction of Itineraries that are Zero Coupon

consumer expectations about their value and the rules that a carrier has for their redemption. Consumers only use them when they think it is a good deal to do so. This means that the price that would have been paid for a zero coupon itinerary tends to be more than the price for the typical itinerary. In other words, zero coupon tickets tend to go to more exotic places (trip to Hawaii rather than to Florida) than other trips. Second, they are driven by price expectations. Airlines are currently expecting record use of zero coupon tickets this summer because of the unusually high price of travel associated with high fuel prices. During periods of increasing prices there is an increased use in the coupons.

Other complications also arise when considering how to handle zero coupon tickets and where they should be included in the CPI. When first introduced, they clearly were linked to
offering more travel for a given fare and could appropriately be viewed as a price reduction. This view is seriously blurred as other companies began offering frequent flyer miles as part of the inducements to use their services. Initially these were travel related businesses, car rentals and hotels, but this has proliferated to clearly nontravel related businesses such as credit cards, long distance phone service.

One approach would be to try to determine the value of a frequent flyer mile to the public and subtract this off from the price of whatever service or product it was connected with. This requires that track of these price adjustments in several different markets be considered. Another approach, the approach taken here, is to impute the value of the tickets using the average fare that would have been paid and constructing a CPI adjustment = expected price of purchased tickets/(imputed value of zero coupon tickets + expected price of purchased tickets). One should hold constant quality characteristics when computing these expected prices and values of tickets. Another, simpler but perhaps less clean way to handle this is to simply incorporate all zero coupon tickets as adjustments into the airline component. This approach is not taken here because it fails to account for the skewed quality distribution of zero coupon tickets. Accordingly, we multiply our hedonic price index by \(1 - s_0 \cdot \lambda_0\), where \(s_0\) is the proportion of zero coupon tickets in any given quarter and \(\lambda_0\) is the CPI adjustment just described. This treatment for zero coupon tickets brings inflation down, but is not the driving force behind this paper's low inflation estimates. With the zero coupon adjustment, average annual inflation is found to be 4.69%, while the average annual inflation without the zero coupon adjustment is found to be 5.11%. 
6. Results and Concluding Remarks

6.1. Index Number Comparisons

The replicated airfare indices for arithmetic and geometric means are presented along with the actual airfare index calculated by the BLS in Figure 6.1. First, note that the replicated indices match fairly well with the actual index. This indicates that deviations from BLS methodology did not have a substantial impact and validates the use of these replicated series for comparison to an index based on hedonic regression.

What differences there are between the replicated arithmetic mean series and the replicated geometric mean series are in the direction expected. The replicated arithmetic mean
series, with weights that are not entirely fixed, has a higher rate of inflation (average annual inflation - 10.19%). While the replicated geometric mean series, also with weights that are not entirely fixed, has a lower rate of inflation (average annual inflation - 8.84%). This supports the notion that geometric means lead to lower estimates of inflation but also suggests that geometric means do not lower estimated inflation substantially.

Comparing the these indices with the hedonic index leads to an interesting conclusion. The Hedonic index has an average annual inflation of 4.69%. This is much lower than any of the other indices. Specifically, the difference between the replicated indices and the hedonic index is much larger than the difference between the replicated indices and the actual CPI index. This seems to imply that quality adjustment issues are more important to correcting upward biases in the airfares index than both fixed weight/basket and aggregation issues. However, this result is directly contradicted by the bench mark regression. This bench mark regression estimates a simple fixed effects model with time dummies but no quality variables. The average annual inflation resulting from this model is 4.42%. This indicates that adjusting for quality increases inflation by a small amount. The appropriate conclusion can only be that quality fell by a small amount during the period 1979 to 1992. Also, the difference between the replicated indices and the bench mark hedonic index is much larger than the difference between the bench mark hedonic index and the hedonic index with quality variables. This suggests that having a market basket determined by sales in each period (and appropriately aggregating) lowers inflation much more than adjusting for quality raises inflation. Thus substitution bias is more important than quality bias in our sample
period. One reason may be the very small amount of routes included in the BLS market basket (approximately 670). The DB1A data set can identify over 134,000 different routes in the sample period. It seems hard to believe that all substitution biases are dealt with when the consumer can only substitute among 0.5% of the total routes. Quality adjustments are still important in order to avoid all bias (in this case downward bias). It seems likely that this fact would hold for many of the sub-indices that make up the CPI (especially indices tracking service oriented industries and high-tech appliances). Thus, complete correction of bias in the CPI (upward or downward) may not be attainable without methods to more accurately control for quality. Since the U.S. economy is becoming increasingly service oriented, quality adjustments will become more and more important to an accurate COL index. However, given the very large importance of substitution issues a clear and immediate policy implication is that the BLS should look into acquiring new sources of data such as scanner data to change (and expand) the market basket and the weights associated with it as frequently as possible. Figure 6.2 (Table 6.1) provides a summary comparison of the different indices used for this paper.

6.2. Data Issues

The primary data set includes a one in ten sample of all tickets issued from January 1979 through December 1992 in US DOT’s DB1A. These are aggregated so that all tickets with the same fare, airlines and plane changes are grouped together. This leads to the loss of some potentially useful information such as date and time of day, flight number and equipment type. DOT further limits other information which appears on the actual ticket such as
| Table 6.1 | A Comparison of Different Indices |
|---|---|---|---|---|---|---|
| RJIS Air Index | DEIA Arithmetic Mean | DEIA Geometric Mean | Bench Mark Hedonic Model | Hedonic Index | Hedonic Index w/ Ticket Restrictions |
| Data Source | SABRE | DEIA | DEIA | DEIA | DEIA | DEIA |
| Fixed Route | Yes | Yes | Yes | No | No | No |
| Fixed Class | Yes | No | No | No | No | No |
| Fix Wgt. Area | Yes | No | No | No | No | No |
| Fix Wgt. US | Yes | Yes | Yes | No | No | No |
| Geo Mean | No | No | Yes | NA | NA | NA |
| Arith. Mean | Yes | Yes | No | NA | NA | NA |
| Quality Adj. | No | No | No | Yes | Yes | Yes |
| Zero Group Adj. | No | No | No | Yes | Yes | Yes |
| Avg. Yearly Inf | 9.00% | 10.19% | 8.84% | 4.42% | 4.69% | 5.27% |

Figure 6.2: Table 6.1 - Index Breakdown

the complete fare class which includes restrictions advance purchase, Saturday night stay, refundability and other restrictions. For this study, the only available fare information which is consistently given over time is whether the ticket is first class or coach. All restrictions are lumped together as discounted.

Before they eliminate information on time of day and date of travel, DOT uses this information to identify trip breaks, and consequently identifies the ultimate destination of travel. In some cases this can unambiguously be done: if there are two flight segments and the second ends where the first began, it is clearly a round trip ticket with the destination at the end of the first segment. If there are three trip segments things become less clear. The ultimate destination is most likely the place with the longest break. On the other hand, such a ticket could be associated with travel with both the city at the end of the first segment and the city at the end of the second segment were destinations. Over the time
period of our study, DB1A included tickets with up to 23 segments. In some cases these are listed simply as round trip tickets (remind me not to use their travel agent). Since we have less information than DOT had to make judgements about what the ultimate trip purpose was, we are in no position to "fix" these tickets. Still, leaving these complex tickets in the sample would seriously compromise our study, since they would indicate high priced very low quality (because of all of the plane changes and indirect routing) service. In our study we segment the tickets into 3 groups, relatively simple one way tickets, relatively simple round trip tickets, everything else. Our relatively simple one way tickets are identified as one destination tickets (one trip break) with fewer than three trip segments. This last condition, eliminated approximately 3% of all one way tickets. Similarly, our relatively simple round trip tickets which included one trip break and the trip ended at the origin had less than five segments. These also eliminated approximately 3% of the round trip tickets. The last category, included multiple destination tickets, open jaw tickets comprised approximately ten percent of the total tickets. The result is that our attention on the relatively simple one way and round trip tickets still makes up approximately 87 percent of all domestic travel while eliminating the worst of the measurement errors.

As stated previously, one way and round trip tickets are considered to be fundamentally different in terms of both the passenger and airline behavior to these services. Consequently, models are developed which treat them separately and the results are discussed before combining them to get an overall model for air travel.
6.3. Aggregate Air Travel CPI and Zero Coupons

One needs to combine together the one way and round trip models together with the zero coupon trips in order to construct an overall price index. These zero coupon tickets occur as a result of frequent flier programs and as compensation for other aspects of service quality such as a passenger being bumped on an oversold flight. It is important to recognize these two different sources because they have different patterns of accumulation and use. Consider the frequent flier awards first.

One expects that zero coupon trips will be systematically different than trips which are paid. Frequent flyer awards typically allow the passenger the opportunity to fly anywhere in broad categories for free (zone A, continental US, world). Consequently, it is anticipated that passengers will cash them in for trips that are more expensive than the average paid flight. Note other aspects of frequent flier awards, such as upgrades are already incorporated into the study through lower paid fares for a given class of service. The value of a zero coupon is imputed ticket as:

\[ \hat{p}_{ijt} = \exp \left( \alpha_t + \beta_t + \sum_{k=1}^{K} \gamma_k X_{k,ijt} \right) \]

The total value of service which is not paid is the sum of the predicted prices summed up over all tickets and service type (one way or round trip). If the distribution of tickets followed the same pattern of routes and service qualities that other paid tickets did, then the average predicted price at any particular time period would simply be \( \exp (\beta_t) \) and one
could compute the discount associated with free travel as:

\[
\text{discount}_t = \frac{k_1 \exp(\beta_{t,1}) + k_2 \exp(\beta_{t,2})}{(k_1 + k_{10,t}) \exp(\beta_{t,1}) + (k_2 + k_{10,t}) \exp(\beta_{t,2})}
\]

where \(k_1\) and \(k_2\) are the weights associated with one way and round trip tickets. Incorporating this into the price index one gets

\[
\text{PriceIndex}_t = \left[ \frac{k_1 \exp(\beta_{0,1}) + k_2 \exp(\beta_{0,2})}{(k_1 + k_{10,t}) \exp(\beta_{0,1}) + (k_2 + k_{10,t}) \exp(\beta_{0,2})} \right] \frac{(k_1 \exp(\beta_{t,1}) + k_2 \exp(\beta_{t,2}))}{(k_1 \exp(\beta_{0,1}) + k_2 \exp(\beta_{0,2}))}
\]

where \(\exp(\beta_{0,1}) = \exp(0) = 1\) and \(k_{10}\) and \(k_{20}\) are the weights associated with zero coupon tickets at each time period. In cases where the zero coupon tickets comprise a different mix of routes and service qualities then the computation of the price index becomes considerably more complex. In this case, \(\exp(\beta_{t,1})\) and \(\exp(\beta_{t,2})\) need to be replaced with the predicted prices adjusted for average service quality differences. This results in:

\[
\text{PriceIndex}_t = \left[ \frac{k_1 \exp(\beta_{t,1}) + k_2 \exp(\beta_{t,2})}{k_1 \exp(\beta_{0,1}) + k_2 \exp(\beta_{0,2})} \right] \frac{(k_1 \exp(\beta_{t,1}) + k_2 \exp(\beta_{t,2}))}{(k_1 \exp(\beta_{0,1}) + k_2 \exp(\beta_{0,2}))}
\]
where

\[ \hat{P}_{10,t,adj} = \sum_{i=1}^{I} \exp \left( \alpha_i \left( \overline{d}_i - \overline{d}_{i,t} \right) + \beta_{1,t} + \sum_{k=1}^{K} \gamma_k \left( \overline{X}_k - \overline{X}_{k,t} \right) \right) \]

where bars indicate averages and superscripts of 0 indicate averages for only the zero coupon tickets at a particular point in time. This index has the effect of holding quality constant at the average quality levels for paid tickets while adjusting the value of zero coupon tickets, and the discount for incorporating zero coupon tickets, for quality differences.

6.4. Additional Factors in Adjusting for Zero Coupon tickets

It is acknowledged that the approach taken is not perfect with respect to zero coupon tickets in at least three dimensions. First, there are zero coupon tickets which are systematically excluded from the analysis. Because DB1A as the source of information, there is no consistent information about foreign travel (DB1A includes only those trips which incorporate a trip segment within the US). Consequently, because of data limitations, it is suspected that the most expensive zero coupon tickets are systematically left out of the analysis (however, they are also left out of the BLS CPI for airfares). The portion of international zero coupon tickets is most likely higher than the portion of domestic zero coupon tickets so the analysis systematically overestimates the price, even of domestic travel.

Second, this analysis presumes that the reward for travel is incurred at the point of the paid travel, or that a zero coupon ticket which was used in the third quarter of 1991 should be attributed to flights during that same quarter. This is clearly not the case for several reasons. It typically takes some time to accumulate frequent flier miles. They are more likely
to be used for vacation travel which is more likely to occur during the summer. The right thing to do would be to attribute back the value of the ticket to periods where it was earned adjusting for time preference. By not incorporating this complexity, the model assumes an equilibrium condition where miles earned and miles used during any quarter offset. This may be approximately true for periods where frequent flier programs are somewhere near equilibrium, for example, 1979-1985 and 1988-1992. It probably does a poor job where miles earned and used are out of balance. As an example, the years 1986 and 1987 form a period where a price spike for one way travel occurred. Adjusting for disequilibrium in frequent flier programs would serve to moderate that price increase.

Third, there is no way of distinguishing tickets earned with frequent flier miles (which are a natural part of price and consequently should be included in the price index) and those that are the compensation because a passenger voluntarily was denied boarding for oversold flights (which reflect a measure of service quality that should be held fixed and thus excluded from the price index). DOT has historically collected information about the number of complaints received for various reasons. These were not used because people tend to write complaints when they are treated worse than they expect to be treated, not necessarily when they are treated well or poorly.

6.5. Ticket Restrictions

Over the last few decades, airlines have been offering an increasing number of deeply discounted tickets with restrictions. These restrictions vary greatly from ticket to ticket and include: Saturday night stay-over, cancellation penalties, purchase a certain number of days
(30, 60, 90) in advance, inability to request a specific seat, etc. These restrictions have been used to create a discount on all fare classes and should represent a quality reduction to the consumer. For instance, a Saturday night stay restriction will cause many to stay an additional night in a hotel.

It would seem ideal to include such restrictions in the hedonic regression. However, the DB1A data set, although, indicating if a give fare had restrictions, does not state what specific restrictions are associated with each ticket. Thus the only way one can incorporate information about restrictions is to include a dummy variable indicating whether a given flight had a restriction and the parameter estimate would be interpreted as the "average" impact on price of having a restriction.

6.6. Basic Unadjusted Model

As a starting place consider a model in which fares are described over time adjusting only for the route (origin-destination pair). The model estimated is

\[
\ln P_{ijt} = \alpha_i + \beta_t + \varepsilon_{ijt}
\]

for ticket \( j \) on route \( i \) at time \( t \). \( \beta_t \) is the coefficient on a dummy time variable where the reference category is time period 79-1. Since service quality characteristics are not explicitly incorporated in this model, they may be correlated with time or route. The predicted price
ratio from 1979-1 to time \( t \) is:

\[
\frac{P_t}{P_{1979-1}} = \frac{\exp(\alpha_i + \beta_t)}{\exp(\alpha_i + 0)} = \frac{\exp(\alpha_i) \exp(\beta_t)}{\exp(\alpha_i)} = \exp(\beta_t)
\]

The estimates for the one way and round trip models are provided in Figure 6.3 (Table 6.2). Summary statistics including the number of observations, \( N \), and the number of route city pairs, \( N_i \) are also listed. Because the model was estimated using a within estimator, the \( R^2 \) does not incorporate the substantial explanatory power associated with these fixed route characteristics.

These results are useful because, while they do not adjust for the characteristics of service, they do provide a comparison between a method which provides for changing weights among ticket types as opposed to the constant weights used in the BLS consumer price index. This is particularly important because the BLS index has fixed proportions of heavily discounted tickets while this analysis shows that these proportions change substantially over time. The time trend for the one way and round trip indices are presented graphically in Figure 6.4.

These results seem to be fairly consistent with expectations: Because discounting is more likely with round trip tickets (where Saturday night stayovers can be enforced) than in one way tickets, the one way fare index has risen more sharply over time. Note that the three sharp spikes occurring in 1988 and 1989 are attributable to a large number of observations, approximately 90% of the sample, having missing fare class information and consequently excluded from the analysis. The major divergence in these indices occurs after
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Figure 6.3: Table 6.2: Estimates for Benchmark Model
Figure 6.4: Bench Mark Hedonic Index
1985. This is a time when airlines were making major attempts to keep business travelers (more likely to use one way fares) while maintaining the revenue advantages of this price discrimination. Initially, frequent flyer programs were structured so only business travelers could take advantage of them. The proliferation of these programs to all categories of travel is responsible for some narrowing of the gap. It also appears that the round trip price index is much more seasonal in nature, particularly after 1989, with peaks occurring in the first and fourth quarters. It is believed that the increased seasonality is a characteristic of the increased use of yield management practices during this period. Where BLS approaches may track ticket prices holding fare category and restrictions constant, they do not incorporate information about how yield management practices may allow a large number or almost no seats to be available at those fares.

6.7. Model with Service Quality

This model controls for several aspects of service quality. The estimated model is:

$$\ln p_{ijt} = \alpha_i + \beta_t + \sum_{k=1}^{K} \gamma_k X_{k,ijt} + \varepsilon_{ijt}$$

where $X_t$ are measures of service quality. This model controls for the expenditures on food, the number of departures (a proxy for airport size, with a small values indicating service to small communities), the number of segments (more segments indicating a more circuitous trip and required changes of planes), interlining (the requirement that passengers also change airlines when they change planes) and the class of service (dummy indicating first class).
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Figure 6.5: Table 6.3: Estimates for Model with Quality Variables

Food, interlining and departures are incorporated in logged form. These estimates are presented in Figure 6.5 (Table 6.3).

The overall pattern of results seems consistent with expectations. Plots are presented which provide a comparison of the price indices which are unadjusted and those that hold quality fixed for one way (Figure 6.6) and round trip (Figure 6.7) models.

In both cases, they indicate that the price index, controlling for service quality, has risen more than the unadjusted price index. This indicates that service quality has reduced over
Figure 6.6: Bench Mark vs. Actual Hedonic Index - One Way
Comparison of Adjusted and Unadjusted Round Trip Price Indices (base=791)

Figure 6.7: Bench Mark vs. Actual Hedonic Index - Round Trip

time. The largest quality difference appears for one way travel at the end of the sample period.

It is also useful to interpret the individual service quality coefficients in each model. The initial expectation is that passenger food should be positively related to fare. The model yields elasticities of 0.057 and 0.070 for one way and round trip travel, both large and enormously statistically significant. The results suggest that increased departures has a negative effect on price with an elasticity of -0.077 for the one way model and -0.021 for the round trip model. The departures measure is essentially a measure of airport activity, not route activity. It provides a measure of airport size. There are two potential rationales for the parameter estimates. First, the quality of service is higher when more travel is offered
from smaller airports since this lowers the driving expenses of traveling to larger airports to begin the trip. Second, larger airports are usually considered less comfortable than smaller airports. The distance between terminals is smaller and the crowds tend to be smaller in a small airport – making it is easier to navigate through a smaller airport. First class travel is expected to have a positive sign in since it includes more space and amenity for the passenger. This is certainly true in the round trip model where the coefficient is 0.622. It is much less so in the one way model the coefficient is only 0.0098. The rationale for this large difference appears to be attributable to discounting. One way trips during our study period are much less likely to be deeply discounted than round trip tickets. As such, the first class coefficient captures the difference between first class and predominately undiscounted coach travel. On the other hand in the round trip model, the first class coefficient captures the difference between the first class fare and the predominately heavily discounted coach travel.

Theory suggests some mathematically irregular patterns associated with trip circuity. In general, it is expected that more circuitous trips will be of lower quality and consequently will have a negative coefficient. This turns out to be mostly reflected in the coefficients for the one way model. For the round trip model, passengers typically are considered to be more interested in arrival time than departure time. An additional trip segment makes arrival time more uncertain. In round trips for business reasons the arrival time at the destination is most critical. Consequently, passengers typically try to avoid additional segments on the outbound portion of the trip. For travel for personal reasons the arrival time back
at the originating city is more important. Consequently passengers typically try to avoid additional segments on the inbound portion of the trip. This suggests that passengers can arrange things so that one additional trip segment is not that bad if it can be arranged in the part of the flight where uncertainty is not important. If an additional segment is added on both the inbound and outbound parts of a trip then it must add uncertainty in a part of the trip where it is most undesirable. Consequently, one finds that two additional segments (4 segment trips) are more than twice the effect of one additional segment (3 segment trips).

The original model examined the log of the number of segments and did not allow this pattern to be exhibited. Other models which included the circuity of the flight were also considered. This model found a positive relationship between ticket distance and fare. This suggests that passengers do not associate a large negative to the extra time associated with an intermediate city that is far off of a direct path as they do with the uncertainty of having to connect to another plane. In fact, because they get quality for additional frequent flyer miles, they may see a large benefit associated with this. Because of the proliferation of nonairline related sources of frequent flier miles, as well as nonairline related redemption of those awards, it is likely that the value of them has declined since the study period.

Perhaps the most surprising estimates in the model are associated with interlining. An interline occurs when a passenger must change airlines as well as planes. This typically involves less coordinated efforts on the part of the airlines that your trip will occur smoothly (increased likelihood of missed flights and lost luggage). An interlined ticket is typically viewed as a ticket of last resort. With the increase in size of airline networks since deregu-
lation and the increased use of partners, interline tickets are substantially rarer than they were 25 years ago. Indeed, decreased interlining is often cited as a benefit associated with airline mergers. Still, the model shows that consumers pay approximately 21% more for interlined tickets. This is consistent with the following situations involving higher service quality. First, interline tickets are most common in situations involving service to small communities. Second, there is an insurance aspect to an interline ticket when compared to separate tickets on the individual carriers. If the first airline gets to the airport late, the passenger is entitled to some remedies. The carriers also agree to handle the transfer of luggage rather than have the passenger responsible for it. Third, because they are often tickets of last resort, they typically are purchased at the last minute and are less likely to qualify for advance purchase discount (i.e. there is some correlation between interlines and the lack of restrictions that come with a full fare ticket).

Figure 6.8 provides estimates of a new hedonic price index for air fares during the 1979-1992 period as well as the BLS airfare index while Figure 6.9 plots the hedonic price index against the two indices created by replicating BLS methodology using the DOT's DB1A data set.

The hedonic price index is derived from separate one-way and round-trip fare regression models with city pair fixed effects to correct for route specific-heterogeneity. There are about 134,000 city pairs in the sample. Log price is regressed on quality characteristics and time dummy variables which represent the increment in price level solely caused by inflation. The rates of change in the parameter estimates (as one moves from the first time
Figure 6.8: CPI vs. Hedonic Price Index

Figure 6.9: DB1A Replicated Indices vs. Hedonic Price Index
period to the second, and so on) represent inflation. The base period (b) is set at 100. One then takes the rates of change (r) and construct an index around the base period. The index in the next period is $100 \cdot r_{b+1}$. The index in the period after that is $100 \cdot r_{b+1} \cdot r_{b+2}$ and so on. The index in the period previous to the base year is $100 / r_b$. The index in the next previous period is $100 / (r_b \cdot r_{b-1})$ and so on. The results indicate that quality-adjusted air fares have been rather flat over the sample period 1979-1992 averaging about 4.69% inflation per year while the BLS air fare index has averaged about 9.80% inflation per year (and our replications average 10.19% and 8.84% per year). This overestimation is "roughly" proportional to the amount of overestimation found by the Boskin Commission. The source of this overestimation is found to be a failure to adequately control for substitution and is not due to quality adjustments. In fact, the admittedly limited attempts at adjusting for quality causes a slight increase in inflation from 4.42% to 4.69% annually. This indicates that service quality has fallen slightly over the sample period.

A model that included a dummy for restrictions on a first class ticket and restrictions on a coach class ticket has also been estimated. The estimates are presented in Figure 6.10 (Table 6.4).

The variable, F restrt, is a dummy for first class restricted flights while the variable, Y restrt, is a dummy for coach restrictions. The variable FCNew is a dummy variable that corresponds to a change in the way DB1A coded first class tickets. If this variable is not included, the model assumes that the same coding applies, and the restricted parameters lose their meaning. The price index created from this model indicates an average annual
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**Figure 6.10: Table 6.4: Estimates for Model With Ticket Restrictions**
inflation of 6.27%. The implication is that an increased presence of restricted tickets has reduced quality over time and caused the quality-adjusted level of inflation to rise. Inflation is still lower than the BLS (9.80%), but is considerably higher than the basic model. It is not believed that a general restriction dummy can accurately control for the quality of the many different restrictions. However, it is believed that the results suggest further data collection in order to accurately measure inflation in this industry.

6.8. Conclusions

This paper has attempted to take an exhaustive approach to measurement issues in price index construction for the BLS airfare index. While the findings are constrained by data availability and the resource constraints of academic, rather than government research activities, this study has nonetheless been able to pursue a number of the objectives for dealing with the biases that the 1996 CPI Commission recommended be addressed. A detailed protocol for data collection has also been developed along with analysis that can be replicated and can be enhanced by availability of additional data sources. An upward bias in the BLS airfare index is found for the period considered. However, the data and computational resources required to implement the Commission recommendations for the airline industry, one which for historical reasons has a substantial amount of detailed data, is quite onerous and the corrections via the hedonic approach are not without their own problems. Because of issues of practicality and implementability, the goals of the Commission recommendations remain illusive and problematic.
Part II

A Reduced Form Analysis of Market Power in the U.S. Airline Industry

7. Introduction

When United Airways sought to buy USAir in a 4.3 billion dollar deal in May of 2000, CIBC Oppenheimer analyst Julius Maldutis said he expected the airlines to have a "good case" before U.S. regulators because there was no substantial overlap in route structures between the two firms\(^9\). Maldutis' main assumption was that U.S. regulators were concerned about reducing competition in any given set of markets, but were not concerned about an expansion of the number of markets serviced by any one firm. It seems reasonable, however, to believe that when airlines compete on an increasing number of routes, their ability to sustain collusion increases.

When American Airlines and British Airways announced a code-sharing agreement, concerns that the agreement would hurt consumers were so great the U.S. congress held public hearings to investigate the matter. Some of these hearings were even televised\(^10\). However, it is well known that code-sharing has both positive and negative consequences and there was no reason to assume, a priori, that the proposed deal would seriously impact

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\(^10\) Brueckner (1997)
consumers.

Predatory pricing in the airline industry is also an important issue for policy makers. In particular, "window shade" pricing is a primary concern to the Department of Justice and the Department of Transportation. The following quote explains the concept of window shade pricing.

"In 1Q, 1996 an incumbent major airline had 1,220 seats priced at $75 or less in a particular city-pair market. During this same quarter a new entrant implemented service with 11,770 seats priced at $75 or less. In 3Q, 1996 the incumbent responded with 49,760 seats priced at $75 or less. The new entrant was shortly thereafter driven from the market and the incumbent reduced its low fare offerings to 910 seats priced at $75 or less during 1Q, 1997. The incumbent's strategy caused it to lose $3.5 million dollars during this period in this market."\(^{11}\)

This paper examines whether airlines behave in a manner consistent with either collusion or fare wars and what factors might influence that behavior. In addition, the paper investigates whether multi-market contacts help firms to keep prices high, and whether or not code-sharing agreements affect prices. These issues will be addressed with a reduced form analysis and a limited structural analysis. The percentage markup above marginal cost for a carrier servicing a market is regressed on market variables such as the Herfindahl index, industry-wide carrier variables such as the number of code-sharing agreements, and

\(^{11}\)Testimony Of Kevin P. Mitchell; Chairman, Business Travel Coalition; Before the U.S. House of Representatives Committee On Transportation And Infrastructure Aviation Subcommittee; October 21, 1999 regarding The State Of Airline Competition
cross-market variables such as the total sales in other markets. The market is defined by origin-destination city pairs. Previous research has examined market power and collusion in the airline industry as a whole or focused on a handful of specific routes. This paper examines such issues at the market/route level for all routes within the United States.

The primary data set used is the Department of Transportation's Origin and Destination Data Bank 1 A (DB1A) which consists of a continuous one in ten sample of all tickets sold in the United States. The data is collected on a quarterly basis and the sample runs from 1979I to 1992IV. By examining collusion and price-wars on a route-by-route basis, multi-market contact is allowed to play a role in whether firms collude. Previous research in collusion has either focused on industries at the national level, or focused on specific markets in a case study. This paper will address collusion on a market-by-market basis for the entire United States. Thus, it will be broader than a case study but not so aggregated as to miss market-specific situations.

It is important to note that this study considers a market (route) to be neither the US as a whole nor, as in most studies, a trip between origin and destination airports. Instead, a market is considered to be a trip between origin and destination cities. Having the market defined as all flights in the US leads one to the conclusion that regional carriers in different regions compete with each other. Since this is known not to be the case, it is prudent to conduct a more detailed analysis. However, defining a route by airports neglects the competition that airlines face from carriers that fly from different airports within the same city. For instance, if someone were to fly from Houston to Chicago, he or she would have four
combinations of airport pairs to choose from: Bush Intercontinental/Chicago O'Hare, Bush Intercontinental/Chicago Midway, Houston Hobby/Chicago O'Hare, and finally Houston Hobby/Chicago Midway. If the flight were round trip, he or she would have four more airport combinations for the trip back. It is well known that United and American have a considerable share of flights from Bush Intercontinental to Chicago O'Hare because O'Hare is a hub for those two carriers. However, Southwest Airlines has a very large schedule of flights from Houston Hobby to Chicago Midway. Considering a route to be an airport pair would suggest that Southwest does not compete with United and American for flights between Houston and Chicago.

The results indicate that an increase in market concentration, as measured by the Herfindahl index, leads to increases in the Lerner index for markets with a dominant pair of firms but not for markets with one dominant firm. This suggests that markets with a dominant firm may have more price competition than markets with a dominant pair of firms. Airlines that have significant sales in other markets and airlines that service a large number of other markets have a higher markup than airlines which have a smaller share of the national industry — which seems consistent with the claim that firms follow a "golden rule" pricing strategy. Finally, the number code-shared flights has an insignificant, negative impact on a carriers price-cost margins which suggests code-sharing agreements do not hurt competition.

This paper is organized as follows. Section two reviews previous studies of market power in the U.S. airline industry. Section three provides a structural model that provides
motivation for the reduced form analysis. Section four discuss the data sources while section five describes construction of marginal cost estimates. Section six reviews several factors that influence the price of an airline ticket and the changing pattern of these factors over time. Section seven describes construction of the dependent variable - the Lerner index while section eight summarizes how the Lerner index relates to particular types of markets. Section nine presents the model to be estimated and lists the variables in the model. Section ten presents regression results and, finally, section eleven provides concluding remarks.

8. Previous Studies

Using case study data from several markets. Brock (2000) notes three noticeable developments in the airline industry. First, the industry is becoming increasingly concentrated through mergers and through strategic alliances. Second, major firms are responding to smaller firms with increasing episodes of predatory pricing. And Third, tacitly collusive, non-competitive pricing strategies are becoming more prevalent. This paper will look for concrete, econometric evidence of these phenomena by looking at the impact of code-sharing agreements, the number of firms in the market, the number of other markets serviced by each firm and whether the market has a dominant firm with the incentive to start a fare war.

Busse (2001) tests whether variables that describe a firm's financial condition affect the probability of that firm initiating a price war. She uses DB1A data from 1985 until 1992. Rather ingeniously, she uses Wall Street Journal Articles to identify when a price
war occurs and which carriers initiated and participated in the price war. She models the probability of a firm entering a price war as being a function of demand (which she estimates separately), financial indicators and control variables. Her results indicate that firms whose financial measures are in the lowest third of the distribution are more likely by about 5 to 8 percentage points to start a price war. However, she assumes that the motivation for price war stems from deviations from collusive agreements and does not model fare wars as predatory pricing strategies. This paper thinks of a fare war as a weapon used by dominant firms to deter entry and drive out smaller firms.

Alam et. al. (2001) use the directed divergence statistic (ddv) in order to examine parallel pricing strategies for carriers among airport routes. Carriers are found to have parallel pricing strategies if the ddv for the carrier pair is a stationary time series while divergent pricing strategies are characterized by a unit root. Using the Augmented Dickey Fuller test, they find that 36 out of the 57 ddv series where stationary - indicating symmetric pricing strategies between carrier pairs. Further, they find that symmetric pricing strategies are more common in markets with fewer airlines, indicating that markets with few firms are characterized by collusion.

Evans and Kessides (1994) use the fourth quarter version of DB1A from 1984 through 1988 to get data for the 1000 largest routes (airport pairs) in order to test the "mutual forbearance" theory. By regressing log price on a number of route and carrier characteristics and an index of multi-market contact, they find that fares are higher in city-pair markets served by carries with extensive inter-route contacts. This result is consistent with the hy-
hypothesis that airlines live by the "golden rule," i.e., that airlines do not engage in aggressive pricing strategies in markets for fear of what their competitors might do in other jointly contested markets. This paper will also investigate the effect of multi-market contact on airline fares. The key difference between this paper and Evans and Kessides is that the data set covers a much larger range of routes and a longer time period (1979-1992) with quarterly data rather than yearly data. Also, this paper explicitly includes estimates of cost to rule out the possibility that increases in fares are caused by increases in costs.

Armentier and Richard (2000) analyze a multi-market oligopoly model with entry and incomplete information on marginal costs. Given their parameter estimates, they simulate competition under the hypothetical agreement to share cost information. Such exchanges of information are standard when airlines enter into code-sharing agreements. They use DB1A data from the third quarter of 1993 on flights sold by United and American Airlines originating or terminating at Chicago O'Hare where the two are essentially duopolists. They utilize an interesting "structural inference" method to back out estimates of marginal costs, given demand and the airline's production decisions. Their findings suggest that airline profits will go up by allowing exchanges of cost information while consumer surplus is largely unaffected and may even increase. This paper extends this result to all markets in the U.S. by showing that code-sharing agreements do not impact price-cost margins.

Brueckner (1997) constructs a model of international flights with a domestic and international carrier, each with a hub in the country of origin. Tests of this model show that code-sharing agreements benefit consumers. Brueckner points out that code-sharing
agreements have a beneficial and a harmful effect. The beneficial effect is that code-sharing puts downward pressure on fares within the inter-lined markets while the harmful effects are that loss in competition within the inter-hub network (the network joining the hubs of the code-sharing partners) pushes prices upwards. Brueckner finds that the positive effects outweigh the negative effects. This paper finds that the two effects counterbalance each other so that code-sharing agreements do not have an impact on price-cost margins.

9. Structural Motivation

To fully understand how this reduced form analysis might compare to studies of a more structural nature, let us provide a motivational example. Assume that a demand function for each route can be identified and estimated and that \( \eta \) is the inverse demand elasticity that results from this estimation. Further, assume that marginal costs can be identified and estimated from cost and production data for each firm. The profit maximizing condition for any firm can be written as

\[
MR = P + \theta \frac{\partial P}{\partial Q} Q = MC
\]  

\[
P + \theta \frac{\partial P}{\partial Q} \left( \frac{Q P}{P Q} \right) Q = MC
\]

\[
P (1 + \theta \eta) = MC
\]  

(9.1)

(9.2)

where \( \theta \) is the conjectural variations parameter. If \( \theta = 0 \) then \( MR = P = MC \) and the market is perfectly competitive. If \( \theta = 1 \) then \( MR = P (1 + \eta) = MC \) which is the profit maximizing condition for a monopolistic of collusive market. If \( \theta = \frac{1}{n} \) where \( n \) is the
number of firms in the market then \( MR = P \left(1 + \frac{n}{n^*}\right) = MC \) which is the profit maximizing condition for a symmetric, Cournot-Nash oligopoly. With simple algebra, equation 9.1 can be rewritten as

\[
\frac{P - MC}{P} = L = -\eta \theta 
\]  

(9.3)

where \( L \) is the Lerner index or percentage markup above marginal cost.

This paper runs a regression on equation 9.3 after assuming that the conjectural variation is not a parameter, but is instead a function itself. That is, it is assumed that equation 9.3 can be further written as

\[
\frac{P - MC}{P} = L = -\eta \theta (X) 
\]  

(9.4)

where \( X \) consists of several market and control variables. Allowing the conjectural variations to be a function allows for market behavior to change. This will hopefully give some insight on what conditions might lead to a change in market behavior. The function is specifically assumed to be linear \((\theta (X) = \beta X)\) and the equation

\[
L = -\eta \beta X + \epsilon 
\]  

(9.5)

is estimated.

Although a reduced form estimation of this model does not separate \( \beta \) from \( \eta \), it is believed that it can still provide valuable clues as to the factors that influence market behavior.
10. The Data

The DB1A data set includes a one in ten sample of all tickets issued from January 1979 through December 1992. These are aggregated so that all tickets with the same fare, airlines, plane changes and in the same quarter are grouped together. This leads to the loss of some potentially useful information such as date and time of day, flight number and equipment type. DOT further limits other information which appears on the actual ticket such as the complete fare class which includes restrictions on advance purchase, Saturday night stay, refundability and other restrictions. For this study, the only available fare information which is consistently given over time is whether the ticket is first class or coach and whether any restriction was placed on the ticket.

Before they eliminate information on time of day and date of travel, DOT uses this information to identify trip breaks, and consequently identifies the ultimate destination of travel. In some cases this can unambiguously be done: if there are two flight segments and the second ends where the first began, it is clearly a round trip ticket with the destination at the end of the first segment. If there are three trip segments things become less clear. The ultimate destination is most likely the place with the longest break. On the other hand, such a ticket could be associated with travel with both the city at the end of the first segment and the city at the end of the second segment were destinations. Over the time period of the study, DB1A included tickets with up to 23 segments. In some cases these are listed simply as round trip tickets. Since the researcher has less information than DOT had to make judgements about what the ultimate trip purpose was, he or she is in no
position to "fix" these tickets. Still, leaving multi-destination tickets in the sample would seriously compromise the study, since they represent sales in more than one market. In this study only tickets that can be clearly classified as either one-way or round trips with a single destination are used. Up to six total segments are allowed for the flight (a five stop, one-way ticket or a round trip ticket with two stops per leg of the trip). Including only one way and round trip tickets with no more than six total segments eliminates just over 1% of the total data.

For clarity, it is important to define what a coupon segment is. If a consumer purchases a ticket, the itinerary for that ticket contains "coupons" that correspond to flight numbers. If the itinerary involves a change in flight numbers, then there is a new "coupon." Consequently a coupon segment is that part of the itinerary in which the flight number remains the same. It is important to note that this does not correspond perfectly with a stop along the trip. If there is a stop in an itinerary that leads to a change in flight number, then that stop leads to a change in coupon segments. This can occur when the passenger changes plains, but also can occur when the passenger stays on the plane. However, if the passenger stays on the plane during the stop and the airline does not change flight numbers, then there is no new coupon segment. This disconnect between coupon segments and stops will lead to some error when estimating marginal costs and when estimating the impact of the number of stops on price.
10.1. Cost Data

DOT's Form 41/T300, the airline production data set, includes four inputs: labor; energy; flight capital; and a residual category called materials that includes supplies, outside services, and non-flight capital. The data set also includes two outputs: scheduled and a non-scheduled revenue passenger-miles. Additionally, it includes two network traits: stage length and load factor. Flight capital is described by four aircraft attributes; the average size (measured in seats); the average age; and the separate proportions of aircraft in the fleet that are jet powered or wide-bodied designs. The data set includes information for the 17 largest U.S. air carriers that were operating at the time of deregulation, or their descendant airlines. The carriers included are American, Alaska, Eastern, Trans World, United, Braniff International, Continental, Delta, Northwest, Western, Frontier, Piedmont, Republic and Texas International. This provides nearly total coverage of scheduled air traffic by the early 1990's when the data set ends. This information is quarterly and air carrier specific. Attention was restricted to the traditional certificated carriers because routine data reporting for those carriers was well established at the time of deregulation.\textsuperscript{12} The version of the data described in more detail below provides the largest, cleanest data available on the production of US.-scheduled passenger air transport.\textsuperscript{13}

The procedure used in constructing the data set has changed considerably over the last

\textsuperscript{12}New entrants could be added to this data set with some difficulty. However, these carriers have little experience in providing the often burdensome reporting required by DOT Form 41. Noncompliance results in virtually no sanctions. Consequently, new entrant data tend to be of significantly lower quality.

\textsuperscript{13}The construction of the cost data was part of previous research involving Ilia Alam, David Good and Robin Sickles.
decade. As more and more data sources become available, it will change further. One of the most significant factors in these changes has been an adaptation to the changes in the reporting requirements of DOT Form 41. In order to maintain comparability over time, data from all versions of Form 41 must be mapped into a single version. The latest significant revision, which occurred in 1987, eliminated many of the specific functional accounts that were used previously. The most significant changes occurred in the areas of labor, supplies and outside services. This latest version Form 41 data is the most restrictive in that it provides the least detail in most cases. In other instances, the 1985 revision of Form 41 data is somewhat more restrictive. However, many of these changes were in place for only a short period of time. Where the 1985 restrictions were most severe, the 1987-equivalent accounts were estimated. This occurred most seriously in the area of ground-based capital, where lease payments and capitalized leases had to be allocated between flight and ground capital. In other cases, it seemed reasonable to estimate 1985 accounts from the 1987 data provided. The objective was to maintain as much detail as possible in all areas of air carrier production.

The construction of the individual input and output categories is described below. In cases where price and quantity pairs for a specific input or output are constructed, several subcomponents to that input or output are first constructed. These are then aggregated into a single input or output using a multilateral Tornqvist-Theil index number procedure. The result of this procedure is a price index (much like the consumer price index) that aggregates price information for commodities having disparate physical units. When total
expenditures of the input or output category are divided by this price index, an implicit quantity index is produced.

10.1.1. Labor

The labor input was composed of 93 separate labor accounts aggregated into five major employment classes (flight deck crews, flight attendants, mechanics, passenger/cargo/aircraft handlers, and other personal). There is no attempt to correct for differing utilization rates since there is no information on the number of hours worked by the labor inputs. Expenditures in these five subcomponents are constructed from the expenditure data in DOT Form 41 Schedules P5, P6, P7, and P8.

Following the 1987 modification in Form 41, Schedules P7 and P8 were dramatically simplified, eliminating many separate expense accounts. Mechanics and Handlers appear as line 5 and 6 of the new Schedule P6. In order to be more compatible with the new Schedule P6, trainees and instructors were moved into the Other Personnel category. Flight attendant expense was calculated by subtracting accounts 5123 and 5124 from Schedule P5 from line 4 (total flight personnel) on the new Schedule P6. Other labor related expenses—such as personnel expenses, insurance and pension, and payroll taxes—were included as labor expenses. Since labor related expenses are provided on functional lines rather than on an employment class basis, they were allocated to each of the five employment groups on the basis of the expenditure share of that class. After the 1987 Form 41 changes, these three expenditure categories are provided on Schedule P6 as line 10, 11, and 12, respectively. The quarterly total head count of full-time equivalent personnel was found by averaging
the monthly full-time personal plus one-half of the part-time employees over the relevant quarter.

In 1977, Schedule P10 was changed from a quarterly to an annual filing cycle. This meant that allocations of head counts into specific employment categories could not be done directly except for the fourth quarter of each calendar year. Instead, the distribution of head counts among the five labor groups was interpolated using the annual figures. The estimated head count in each group was found by multiplying the interpolated percentage by the calculated full-time equivalent head count for that quarter. In 1983, Schedule P10 was simplified. This simplification collapsed the handlers’ category into a smaller number of separate accounts, but did not change the overall structure of the procedure.

Using the expense and head count information from above, the expense per person quarter and the number of person quarters were calculated. The multilateral Tornqvist-Theil price and quantity indices for the labor input were then derived.

10.1.2. Energy

The objective of the energy input category is to capture aircraft fuel only. Fuel that is used for ground operations and electricity are captured in the materials index. The energy input was developed by combining information on aircraft fuel gallons used with fuel expense data per period. Aircraft fuel cost in dollars comes from Schedule PS, account 5145.1. Gallons of aircraft fuel is listed in Schedule T2, account Z921. This input has undergone virtually no change because these accounts remained substantially unchanged over the span of the data set. Even though only one component exists, the multilateral Tornqvist-Theil index
number procedure is used to provide normalization of the data.

10.1.3. Materials

The materials input is comprised of 69 separate expenditure accounts aggregated into 12 broad classes of materials or other inputs that did not fit into the labor, energy, or flight capital categories. Carrier-specific price or quantity deflators for these expenditure groups were unavailable. Instead, industry-wide price deflators were obtained from a variety of sources. The classification of these expenditure accounts are presented below along with the corresponding source for the price deflator.

In 1987, the modifications of Schedules P6 and P7 led to the elimination of hundreds of separate account categories. In most cases, this did not affect the ability to reconstruct the categories. The sources of information did change, however. Advertising expense, passenger food, and landing fees appear as line 22, line 6, and line 12 of the new Schedule P7, respectively. Expenses for aircraft maintenance materials, communications, insurance, outside services and outside maintenance and passenger and cargo commissions appear as line 17, line 23, line 24, line 25 + line 28, and line 26 + line 27 of the new Schedule P6. Ground equipment rental expense was line 31 of Schedule P6 minus account 5147 from Schedule P5. Amounts for other supplies and utilities appear aggregated together as line 19 of new Schedule P6. These amounts were apportioned to the supplies and utilities categories using the carrier’s average proportion in these groups over the 1981 through 1986 periods. Ground equipment that is owned was unaffected by the 1987 accounting change.
10.1.4. Flight Capital

The number of aircraft that a carrier operated from each different model of aircraft in the airline's fleet was collected from DOT Form 41, Schedule T2 (account Z820). Data on the technological characteristics for the approximately 60 types of aircraft in significant use over the period 1970 through 1992 were collected from Jane's All the World's Aircraft (1945 through 1982 editions).

First, for each quarter, the average number of aircraft in service was constructed by dividing the total number of aircraft days for all aircraft types by the number of days in the quarter. This provides a gross measure of the size of the fleet (number of aircraft).

In order to adjust this measure of flight capital, the average equipment size is also constructed. This was measured with the highest density single-class seating configuration listed in Jane's for each aircraft type. The fleet-wide average was weighted by the number of aircraft of each type assigned into service. In some cases, particularly with wide-bodied jets, the actual number of seats was substantially less than described by this configuration because of the use of first-class and business-class seating. The purpose was to describe the physical size of the aircraft rather than how carriers chose to use or configure them.

As a measure of fleet vintage, this study uses the average number of months used since the FAA's type-certification of aircraft designs. The assumption is that technological innovation in an aircraft does not change after the design is type-certified. Consequently, the measure of technological age does not fully capture the deterioration in capital and increased maintenance costs caused by use. This measure does capture retrofitting older designs with
major innovations, if these innovations were significant enough to require recertification of the type.

Finally, it is clear that conversion to jet aircraft was the major innovation during the 1960's and 1970's. While many carriers had largely adopted this innovation prior to the study period, it was by no means universal. Many of the local service airlines used turboprop aircraft as a significant portion of their fleets and this is controlled for by measuring the proportion of aircraft in the fleet that are jet powered. The proportion of wide-bodied aircraft was also calculated.

10.1.5. Output

The data set provides several measures of airline output and its associated characteristics. The most commonly used measure of carrier output is the revenue ton-mile. This data set provides this measure as well as measures of revenue output that are disaggregated into scheduled and nonscheduled output. Nonscheduled output includes cargo and charter operations. Further, measures of airline capacity are provided. This again can be disaggregated into scheduled and nonscheduled operations. Revenue and traffic data were available from DOT Form 41. These data allowed construction of price and quantities for seven different outputs produced by the typical airline. Again, the price per unit (passenger-mile or ton-mile) of the relevant service as constructed by dividing the revenue generated in the category by the physical amount of output in that category. In cases where a carrier offered only one type of service (the convention was to call this "first class"), the service was redefined to be coach class. The reporting of revenue and traffic charter operations between
cargo and passenger service was very sporadic. These two outputs were combined into a single category with passenger-miles converted to ton-miles, assuming an average weight of 200 pounds per passenger (including baggage). Changes in DOT Form 41 in 1985 led to the elimination of the distinction between express cargo and air freight. Consequently, these two categories were also collapsed. Three different price and quantity index pairs are generated. The first is total revenue-output and uses the multilateral Tornqvist-Theil index number procedure on all the revenue-output categories. The second used the Tornqvist-Theil index number procedure on the two passenger categories. The third results from the use of the index number procedure on mail, cargo and charter services.

The capacity of flight operations is also provided in this data set. This describes the total amount of traffic generated, regardless of whether or not it was sold. While it is possible to distinguish between an unsold coach seat and an unsold first-class seat (they are of different sizes), such distinctions are not logically possible in the case of cargo operations (mail and cargo could be carried in the same location). Consequently, the measure of airline capacity includes only three broad categories: first-class seat-miles flown, coach seat-miles flown, and nonscheduled ton-miles flown. With the change to T100 as the primary data base for airline traffic in 1990, carriers are no longer required to report available seat-miles, revenue seat-miles, or revenues by the level of passenger service. Instead, these amounts are aggregated with revenues supplied as account 3901 on Schedule P1 after 1990.

The convention that passenger along with baggage is 200 pounds (one-tenth of a ton) is used to construct the nonscheduled ton-miles. Potential revenues that could be collected, if
all services were sold, are constructed assuming that the prices for each of these categories remain the same as for output actual sold. In other words, the price for first-class revenue passenger-miles flown is imputed to first-class available seat-miles flown. The Tornqvist-Theil index number procedure is used to generate price and quantity pairs for total capacity output, passenger capacity output, and nonscheduled capacity output.

Two important measures of the carrier's network are also generated. The first is a passenger load factor. This is found by dividing revenue passenger-miles by available seat-miles. This measure is generally related to flight frequency with a lower number indication more frequent flights and consequently a higher level of service. Other definitions of load factor are possible, such as dividing the total passenger revenue collected by the total that would be collected were the planes flown full (derived from the passenger capacity output times passenger capacity price). Stage length also provides an important measure of carrier output. Generally, the shorter the flight, the higher the proportion of ground services required per passenger-mile and the more circuitous the flight (a higher proportion of aircraft miles flown is needed to accommodate the needs of air traffic control). This generally results in a higher cost per mile for short flights than for longer flights. Average stage length is found by dividing total revenue aircraft miles flown by total revenue aircraft departures.

11. Constructing Marginal Cost Estimates

Individual carrier marginal costs are modelled with a Cobb-Douglas cost function:
\[
\ln \text{Cost} = \beta_1 \ln \text{RevPassM} + \beta_2 \ln \text{Enplanements} + \beta_3 \ln \text{CargoTM} \\
+ \beta_4 \ln \text{Cities} + \beta_5 \ln \text{LoadFactor} + \beta_6 \ln \text{P Labor} \\
+ \beta_6 \ln \text{PFuel} + \beta_7 \ln \text{PMaterials} + \beta_8 \ln \text{PCapital} \\
+ \beta_9 \text{time} + \sum_{i=1}^{\text{airlines}} \delta_i \text{airline}_i
\]

The model estimates a scale elasticity of 1.0182 which is not statistically significantly different from 1 at conventional significance levels. The model, while simple, fits well (R\(^2\) = .9956), is globally regular and provides a great deal of information about marginal costs. RevPassM are revenue passenger miles, or the sum of the miles traveled by paying passengers. Enplanements are the sum of the passengers on all flights. (A passenger who is on a flight is not considered to have enplaned if the flight involves a stop. If their itinerary requires that they change flights then a second enplanement would occur for that trip.) CargoTM are the number of cargo ton miles on a flight. Cities provides a measure of the network size for a carrier. Caves Christensen and Tretheway (1984) suggest that this is an important reason why airline costs differ. As the number of cities increases, the density of traffic on the carriers network, holding number of passenger miles constant, tends to decrease. Incorporating LoadFactor into the model allows us to consider changes in revenue passenger miles increase, while holding the number of available seat miles constant. One would expect that increasing revenue passenger miles while holding available seat miles
constant would have a very low cost since it involves simply filling up an otherwise empty seat.

With these estimates carrier specific marginal cost for the passenger’s flight can be calculated as

\[
\text{Terminal Costs} = MC_{\text{enplanements}}
\]

\[
\text{Per Mile Cost} = MC_{\text{repassmi}}
\]

\[
\text{Total Segment Cost} = MC_{\text{enplanements}} + MC_{\text{repassmi}} \cdot \text{miles flown}
\]

Marginal cost is carrier and time specific. For multi-segment trips, the cost of a particular itinerary is estimated by the sum of the cost for the individual trip segments.

\[
\text{Total Itinerary Cost} = \sum_{j=1}^{n\text{segs}} \text{Total Segment Cost}_j
\]

The cost estimates show growth rates that are on average slightly higher than those generated by SIFL. Between 1971-1 and 1992-4 there is an estimated 71.6% increase for a 500 mile trip and an 86.4% for a 1000 mile trip. It is important to mention that these estimates were based on data for the entire U.S. system and not for specific city-pair routes. Cost data from individual routes is simply unavailable. The marginal cost estimates derived from this national data are clearly not as accurate as one would hope. However by incorporating information on the specific number of enplanements, and the specific distance of particular
flights, the marginal cost estimates should be as accurate as possible. As a defense of these estimates it should be pointed out that they correspond very well with the SIFL.

It is important again to bring up the distinction between enplanements, stops, and segments. An enplanement occurs when a passenger boards a plane, a stop occurs when a plane carrying the passenger lands at an airport and a change in segment occurs when a person encounters a new flight number. The marginal cost estimates are for enplanements because the cost data is measured in enplanements. Ideally, the costs would be measured in stops because there is a large cost associated with each stop, regardless of whether the passenger boarded a new plane. Also, ideally the price data would be broken down by stops because the passenger should regard any stop as an inconvenience, not just stops that involved a change in flight number. However, it is broken down by segments. When imputing the marginal cost of any given flight using DB1A data the best proxy for an enplanement is the coupon segment. There will be some over-estimation when imputing costs from DB1A using cost data because some changes in segment occur without an enplanement. However there will also be some under-estimation because when using the cost data because some stops where no flight number changed will not be counted as an enplanement. Again, however, the resulting cost estimates do correspond with the SIFL.

12. Pricing Issues in The Airline Industry

The goal of this paper is to find evidence of collusion and fare war. This is done by regressing the percentage markup above marginal cost (Lerner index) on a number of market and
industry variables. However, there are several other variables that would cause the Lerner index for a particular carrier on a particular route to change. These variables should be included into the analysis as control variables. These variables can be put into five broad categories: Route specific effects, ticket restrictions, yield management, zero coupon tickets and network effects.

12.1. Route Specific factors

There are clearly other variables which many have attempted to incorporate into modeling the demand side of long distance travel. These include factors which are weather related, such as mean temperature difference, in an attempt to capture vacation travel in the winter months. Others have included variables which attempt to capture the demand for business travel such as the number of white collar jobs in an area. The model for this paper assumes that these factors are either very slow to change or that they are strongly correlated with other factors in the model. These slowly moving factors are captured with fixed route specific effects which describe the origin-destination pair. There are 92,896 route effects in the data.

12.2. Ticket restrictions

A major feature of airline fare structures is ticket restrictions. These either increase the risk of travel for consumers (non-refundability) or provide the airlines with improved predictability about demand (advanced booking) and enhance their ability to provide price discrimination information by separating price sensitive consumers from business travelers.
Figure 12.1: Fraction of Itineraries that are Discounted Coach

with more inelastic demands (Saturday night stay-overs). The major liability of using of DOT’s DB1A as the primary source of ticket information is that it includes very incomplete information on ticket restrictions. There is typically a lag between fare type innovations and the way they are reported in DB1A. This makes it difficult to identify a consistent set of conditions under which service was accepted. All that can be consistently identified from the fare class codes is whether or not some kind of discounting was used on a particular ticket. These are summarized in Figure 12.1 which describes the fraction of all tickets which were discounted coach tickets for one way and round trip travel. The data shows a steady increase in both one way and round trip tickets that are discounted coach. For round trip tickets, this involved only 30% of tickets being discounted coach in 1979-1
increasing to nearly 90% of the round trip tickets being discounted coach by 1992-4. The three large declines in 1988 and 1989 are quarters in which virtually all fare information was not recorded by DOT. Restrictions are controlled for by calculating the percentage of first class and coach restricted tickets sold by the carrier for a particular route.

12.3. Yield management

There is a great deal of competitiveness in the published fares. It is not at all uncommon for different airlines providing service on the same route to offer similar fare classes (sets of fare restrictions) at an identical price. But their fare structures may be radically different because of yield management practices. Many of these published fares may simply be unavailable. They will certainly occupy different fractions of the seats sold on a particular flight or in a particular market. It would be inappropriate to model the situation as though the fare described the price at which people were just willing to accept the particular restriction. Because of this lack of availability of different fares consumers typically will meet higher sets of fare restrictions than those actually required by their ticket. For example, a consumer may meet the 30 day book in advance, no refund, Saturday night stay restrictions, but because this fare is sold out, they may accept a 14 day book in advance, no refund, Saturday night stay fare. This paper attempts to capture the effect of yield management by including the percentage of first class, first class restricted, and coach restricted tickets in the model. Figure 12.2 characterizes the fraction of first class tickets for round trip itineraries. It tracks the gradual decline in the use of first class.
12.4. Zero coupon tickets

Frequent flyer miles were introduced in the mid 1980s by perhaps the leader of brutal competition, Robert Crandall at American Airlines. The purpose behind this technique was to increase customer loyalty to a particular airline by offering them free travel at a later date. This technique has proven so successful that it has proliferated to other industries, even grocery stores offer discounts for frequent shoppers. The pattern of these tickets over time is described in Figure 12.3 for one way and round trip travel. For both round trip and one way travel there is a spike in 1987 associated with the introduction of these tickets to about 10 percent of both one and round trip travel. By 1988, these decline to about 5% of round trip travel and about 4% of one way trips. The Lerner Index of a zero coupon ticket is minus infinity. This problem is dealt with by aggregating to the market level. Average price and average cost are used to construct and average markup over cost the carrier receives by servicing the route. To control for the effects of zero coupon tickets markups above marginal cost, the percentage of zero coupon tickets sold by the carrier for a particular route is included.

12.5. Network Configuration

Much has been made out of changes in airline networks by increased use of hub-and-spoke type networks. Airlines find these network configurations useful because they allow for higher passenger densities on individual routes. For example, in a simple network involving 5 cities (one centrally located), these cities can be connected with at most one change of
Figure 12.2: Fraction of Round Trip Itineraries that are Round Trip

Figure 12.3: Fraction of Itineraries that are Zero Coupon
plane service with as few as 4 flights. Connecting these cities together with a network where there is nonstop service would require 20 flights.

Indirect routing of passengers clearly benefits the airlines because they can provide travel to passengers with fewer flights, potentially taking advantage of economies of equipment size (larger aircraft tend to have lower costs per passenger mile) and higher load factors (filling otherwise empty seats on an aircraft cost the airline very little).

In general, indirect routing of passengers is something that passengers would like to avoid. Their time is valuable. Indirectly routing a passenger, especially when it involves changes of planes is definitely less desirable than a direct flight. There are some exceptions to this. Indirectly routed passengers often will accrue more frequent flyer miles than a directly routed passenger.

Many of these different network characteristics can be measured at the individual ticket level. The Department of Transportation's Origin/Destination database DB1A provides a 10% sample of all domestic tickets and allows identification of many of the characteristics of the trip. Most fundamentally, the origin of a trip can be identified as well as the ultimate destination as indicated by a trip break. Approximately 95% of trips are either one way or round trip (depending on the year) with a small number of multi-break tickets involving as many as 23 different flights. More complex routings tend to be slightly more prevalent in later years than in earlier ones. In order to gain an understanding of the bulk of trips, attention is limited to either one way or round trip tickets. The changing pattern of these tickets is described in Figure12.4.
Figure 12.4: Average Number of Ways

Typically, two thirds of the tickets are round trip. This declined about 10 percent in the mid 1980s but returned to its previous levels by the end of the decade. For the purposes of this paper, a one-way and round trip ticket differ only in the price and the marginal cost which is picked up in the Lerner index. Consequently, one-way and round-trip tickets are pooled into the same data set. However, to control for the fact that round-trip tickets are always less than twice the cost of a one-way ticket, the percentage of round trip tickets is included in the model.

The information from the Origin and Destination data also allows measurement of the number of segments in a ticket. These are summarized by the variable CSEGS for one way and round trip tickets in Figure 12.5. To control for the effect of the number of segments in the itinerary, the percentage of tickets with any number of in-between segments up to 2
in-between segments is included. Again recall the caveat that an increase in stops does not always correspond with an increase in segments.

Figure 12.5 shows that approximately half of the one way itineraries involved an additional segment in 1979-1. But, by 1984, this number fell to 25%. A very different pattern emerges for round trip tickets which have a minimum of two segments. In 1979-1 the average number of segments was 2.8, this increased somewhat to 3.05 by 1992-4. At 3.0 it suggests that approximately half of the itineraries involved a change of flight number on the outbound and inbound portions of the trip. The rationale behind the difference in the one way and round trip ticket patterns is not clear. It may suggest a correlation between one way and full fare tickets which have a higher quality of demanded service for the large
premium in price. On the other hand, while the presumption behind round trip tickets is that they describe the full trip, that is not the case for one way tickets since the passenger will require, at the minimum, an additional ticket for the return flight. Consequently the presumption that a full fare ticket involves the ultimate destination seems less well founded.

Finally, in an attempt to control for the effects of hub-and-spoke networks, the total number of tickets sold by the carrier in both the origin and destination city is used. If the carrier operates a hub in either of the cities, the number of tickets sold should be much greater than the number of tickets sold for other carriers.

13. Constructing Lerner Indices

After estimating marginal costs, a data set is constructed with four variables, carrier, date, $MC_{enplanement}$, $MC_{repassm}$. This data set is then merged, segment-by-segment with the DB1A data. Merging is done segment-by-segment because code-sharing gives rise to flights with more than one carrier, and the appropriate costs to each carrier should be assigned for every segment rather than assign the costs of the carrier whose name happens to be on the ticket. The Total Itinerary Cost is constructed by the formula

$$Total\ Itinerary\ Cost = \sum_{i} MC_{i,\ carrier_i}^{enplanement} + MC_{i,\ carrier_i}^{repassm} \cdot distance_i$$

where $i$ indexes segments and $carrier_i$ is the carrier that actually flew on segment $i$. The marginal cost estimates are derived from national level cost data and are in line with published Standard Industry Fare Level (SIFL) values.
A Lerner Index cannot be constructed for each individual ticket because zero coupon tickets will have a Lerner Index of minus infinity. So, the data is aggregate up to the route level. The average price of all tickets sold by a particular carrier along a particular route in any given quarter and the corresponding average cost are calculated. Then the Lerner Index is constructed as

\[
L_{n,m,t} = \frac{\text{Avg Price}_{n,m,t} - \text{Avg Cost}_{n,m,t}}{\text{Avg Price}_{n,m,t}}
\]

where \( n \) indexes the carrier, \( m \) indexes the route and \( t \) indexes the quarter. This allows the inclusion zero coupon tickets into the analysis. Including zero coupon tickets is very important for analysis of predatory pricing because fare wars may be partially fought through frequent flyer programs and promotional programs such as "Friends Fly Free."

14. Market Structure and the Lerner Index

Table 14.1 lists the average Lerner index for various types of markets. Several interesting implications arise from these numbers.

First, monopoly markets seem to have a low Lerner index compared to other markets. This, however, is largely because monopoly markets tend to be very small markets which are associated with high costs. Duopolies tend to have reasonable markups above marginal cost. Duopolies also tend to have higher profits than triopolies. However, triopolies with a dominant firm have higher markups that any kind of duopoly. Triopolies with no dominant firm seem to be in intense price competition - to the point of losing a large amount of
<table>
<thead>
<tr>
<th>Type of Market</th>
<th>Average Lerner</th>
<th># of Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monopoly</td>
<td>0.0085341</td>
<td>554619</td>
</tr>
<tr>
<td>Dominant Firm</td>
<td>0.1293818</td>
<td>1228838</td>
</tr>
<tr>
<td>Dominant Pair</td>
<td>-0.0295485</td>
<td>1300856</td>
</tr>
<tr>
<td>Duopoly</td>
<td>0.0085341</td>
<td>582845</td>
</tr>
<tr>
<td>Dominant Firm</td>
<td>0.0834879</td>
<td>431846</td>
</tr>
<tr>
<td>No Dominant Firm</td>
<td>0.0937389</td>
<td>142576</td>
</tr>
<tr>
<td>Triopoly</td>
<td>-0.3100364</td>
<td>486525</td>
</tr>
<tr>
<td>Dominant Firm</td>
<td>0.1327575</td>
<td>271253</td>
</tr>
<tr>
<td>No Dominant Firm</td>
<td>-1.5459704</td>
<td>215108</td>
</tr>
<tr>
<td>Quadopoly</td>
<td>-0.0188711</td>
<td>393473</td>
</tr>
<tr>
<td>Dominant Firm</td>
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<td>172619</td>
</tr>
<tr>
<td>Dominant Pair</td>
<td>0.0485526</td>
<td>220849</td>
</tr>
<tr>
<td>Neither</td>
<td>-0.8936405</td>
<td>5</td>
</tr>
<tr>
<td>5 or More Firms</td>
<td>0.0750406</td>
<td>1078799</td>
</tr>
<tr>
<td>Dominant Firm</td>
<td>0.1661612</td>
<td>353120</td>
</tr>
<tr>
<td>Dominant Pair</td>
<td>0.0196283</td>
<td>722323</td>
</tr>
<tr>
<td>Neither</td>
<td>-0.0476201</td>
<td>3356</td>
</tr>
</tbody>
</table>

Table 14.1: Markup by Market Type

money. Quadopolies tend to lose money as well. However, quadopolies with a dominant pair of firms are profitable - suggesting collusion may be occurring. Markets with five or more firms tend to earn very high returns per ticket. These markets tend to be in the most populated cities with high demand. As a result, these are markets with hubs for major airlines (hence the small number of markets without a dominant firm or dominant pair).

15. The Model

The model to be estimated is

$$L_{n,m,t} = \alpha_m + \beta X_{n,m,t} + \varepsilon_{n,m,t}$$ (15.1)
where $\alpha_m$ is the route specific fixed effect and $X_{n,m,t}$ includes market and control variables. The variables to be used are (By excluding the dummy for AA and a dummy for quarter 1, the "default" itinerary is ticket sold by AA that flew during the first quarter.):

- **Monopoly** – A dummy that is 1 if the market is a monopoly.

- **Duopoly** – A dummy that is 1 if the market is a duopoly

- **Triopoly** – A dummy that is 1 if the market has 3 carriers

- **Quadopoly** – A dummy that is 1 if the market has 4 carriers

- **Dominant Firm** – A dummy that is 1 if the market is not a monopoly and a carrier serving that market has greater than a 60 percent share

- **Dominant Pair** – A dummy that is 1 if the market is not a monopoly, no one firm has a 60 percent share but the two largest firms have at least a 60 percent share

- **Lagged Herfindahl** – The Herfindahl index for the market. This index will be included as is, and also split up into two sub-variables. These variables are lagged because market shares are endogenous. We assume lagged values are pre-determined and, thus, exogenous.

  - Lagged (Herfindahl$\times$Dominant Firm) – Herfindahl index for all markets with a dominant firm.

  - Lagged (Herfindahl$\times$Dominant Pair) – Herfindahl index for all markets with a dominant pair.
- 4FirmConcentration – The 4 firm concentration ratio in the market.

- CodeShare – The number of code-share flights flown by a particular carrier across all routes. This variable is defined on the carrier level rather than the market level in order to measure the possible effects that code-sharing arrangements might have on incentives to collude. Since code-sharing agreements are made between carriers, the effects of those agreements should be made at the carrier level.

- SalesOtherMkts – The total sales in all other markets by the carrier. This variable should help reveal whether multi-market contact plays a role in price-cost margins.

- #OtherMkts – The number of other markets serviced by the carrier. Again, this variable should help reveal whether multi-market contact plays a role in price-cost margins.

- International Airport – A dummy that is 1 if the route involves a city with an international airport. This variable should help control demand effects.

- %RoundTrip – The percentage of all tickets sold by the carrier that were round-trip.

- %ZeroCoupon – The percent of all zero coupon tickets given away by the carrier on the route in question.

- %FirstClass - The percent of all segments that are unrestricted-first class. It is the proportion of all segments because several itineraries have different fare classes for different segments of the trip.
• %FirstClassRestricted – The percent of all segments that are first class with some restrictions.

• %CoachRestricted – The percent of all segments that are discounted coach tickets.

• %Half-Stop, %1HalfStop – Because both round-trip and one-way tickets are included, a method for comparing the number of stops had to be devised. Since a round trip ticket has two legs, having two total stops seems equivalent to a one-way ticket with one stop. Hence, the number of stops is defined to be \( \frac{\text{#stops}}{\text{#legs}} \). A round trip itinerary with a stop on one leg of the trip, but where the other leg of the trip is non-stop is considered to be a half-stop itinerary. %HalfStop is the percentage of all itineraries that are "half-stop" and %1HalfStop is the percentage of all itineraries that are round-trip with three stops.\(^{14}\)

• %1stop,%2stop – The percentage of all itineraries that have either 1 stop, or 2 stops.

• CityTix – The total number of tickets sold by the particular carrier that flew out of either the origin or destination cities. This variable should control for congestion effects.

• Qtr2, Qtr3, Qtr4 – Quarter dummies to pick up seasonality.

• AL, BN, CO, DL, EA, FL, NW, PI, RC, TI, TW, UA, WN – Carrier dummies

• Gulf War – A dummy that is 1 during the gulf war. (1990)

\(^{14}\)Note the previous caveat concerning the number of stops and the number of in-between segments. A change in segment involves a change in flight number which does not always occur with a stop.
• Iran Iraq – A dummy that is 1 during the Iran Iraq war (1980III-1988III)

• Air Traffic Controller’s Strike – A dummy that is 1 from the start of the air traffic controller’s strike through the last quarter in which flights were restricted due to the firing of air traffic controllers (1983I-1984I)

• CO Pilots’ Strike – A dummy that is 1 for CO during its pilots’ strike (1983IV-1985II)

• UA Pilots’ Strike – A dummy that is 1 for UA during its pilots’ strike (1985II)

• EA Pilots’ Strike – A dummy that is 1 for EA during its pilots’ strike (1989I-1989IV)

• EA Mechanics' Strike – A dummy that is 1 for EA during its mechanics’ strike (1983I-1984I)

• RC Merge HA – A dummy that is 1 for RC after its merger with Hughes Air became official (1980IV)

• CO Merge TI – A dummy that is 1 for CO after its merger with TI became official (1983IV)

• NW Merge RC – A dummy that is 1 for NW after its merger with RC became official (1986IV)

• TW Merge OZ – A dummy that is 1 for TW after its merger with OZ became official (1986IV)

• CO Merge FL – A dummy that is 1 for CO after its merger with FL became official (1987I)
• AA Merge CL – A dummy that is 1 for AA after its merger with Air Cal became official (1987II)

• DL Merge WN – A dummy that is 1 for DL after its merger with WN became official (1987II)

• DL Merge PA – A dummy that is 1 for DL after its merger with Pan Am became official (1991IV)

• CO And EA – A dummy that is 1 for CO and EA after EA became part of the larger Texas Air holding company (1986IV)

• Avg Dist, (Avg Dist)² – The average distance and squared average distance of a route. A change in these variables occurs because flights become more or less direct. The percentage stop variables account for changes in the number of in-between segments, while the distance variables account for the changing proximity of stops.

There are clearly other variables which many have attempted to incorporate into modeling the demand side of long distance travel. These include factors which are weather related, such as mean temperature difference, in an attempt to capture vacation travel in the winter months. Others have included variables which attempt to capture the demand for business travel such as the number of white collar jobs in an area. The model for this paper assumes that these factors are either very slow to change or that they are strongly correlated with other factors in the model. These slowly moving factors are captured with fixed route specific effects which describe the origin-destination pair. There are 92,896 route
## Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DOF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-value</th>
<th>Pr &gt; F</th>
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</thead>
<tbody>
<tr>
<td>Model</td>
<td>60</td>
<td>8.63×10^{10}</td>
<td>1.44×10^{9}</td>
<td>35.78</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Error</td>
<td>2.74×10^{6}</td>
<td>1.00×10^{11}</td>
<td>3656.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2.74×10^{6}</td>
<td>187×10^{11}</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Root MSE</td>
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<td>60.467</td>
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<tr>
<td>Dependent Mean</td>
<td>-0.3582</td>
<td>Adj. R-Sqr</td>
<td>0.4629</td>
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<tr>
<td>Coeff. Var</td>
<td></td>
<td>53795</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 16.1: Fixed Effects Model

Effects in the data. With just over three million observations and just under one hundred thousand effects, the average number of observations per cross-section is quite low. This may imply that the regressors have relatively little explanatory power when compared to the effects.

### 16. Regression Results

Regression results are listed in Tables 16.1 through 16.5. A fixed effects model was estimated using weighted least squares in order to control for heteroskedasticity arising from aggregation and in order to prevent estimates being driven by outliers from small markets.

First, being a monopoly in a market brings price-cost margins up, as expected ($\beta_{Monopoly} = 4.74$). The effect of being a duopoly is more complicated. For duopolies where one firm has a dominant share of the market, the impact on price markups can range from a minimum of 4.43 to a maximum of 4.51 ($\beta_{Duopoly} + \beta_{Dom Firm} + \beta_{Herf Dom} \times (5200, 10000)$). Duopolies where no firm has a dominant share of the market have markups that can range from a minimum of 4.698 to a maximum of 4.704 ($\beta_{Duopoly} + \beta_{Dom Firm} + \beta_{Herf Pair} \times (5000, 5200)$).
<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Std. Err.</th>
<th>t Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monopoly</td>
<td>4.74004</td>
<td>0.19161</td>
<td>24.74</td>
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<td>Duopoly</td>
<td>0.17792</td>
<td>0.04935</td>
<td>3.61</td>
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<tr>
<td>Triopoly</td>
<td>0.08301</td>
<td>0.03892</td>
<td>2.13</td>
</tr>
<tr>
<td>Quadopoly</td>
<td>-0.00163</td>
<td>0.03150</td>
<td>-0.05</td>
</tr>
<tr>
<td>Dom. Firm</td>
<td>4.37482</td>
<td>0.19630</td>
<td>22.29</td>
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<tr>
<td>Dom Pair</td>
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<td>LagHerfindahl</td>
<td>0.000022</td>
<td>7.58×10⁻⁵</td>
<td>2.92</td>
</tr>
<tr>
<td>LagHerf×DFrn</td>
<td>-0.00008</td>
<td>6.28×10⁻⁵</td>
<td>-1.29</td>
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<tr>
<td>LagHerf×DPr</td>
<td>0.000045</td>
<td>8.43×10⁻⁵</td>
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</tr>
<tr>
<td># Other Rts</td>
<td>0.000024</td>
<td>4.60×10⁻⁵</td>
<td>5.13</td>
</tr>
<tr>
<td>Sales Oth Rt</td>
<td>1.2×10⁻¹⁰</td>
<td>3.5×10⁻¹¹</td>
<td>3.50</td>
</tr>
<tr>
<td>Codeshare</td>
<td>-8.24×10⁻⁷</td>
<td>6.88×10⁻⁷</td>
<td>-1.20</td>
</tr>
<tr>
<td>% Zero Coup</td>
<td>-4.49612</td>
<td>0.10318</td>
<td>-43.57</td>
</tr>
<tr>
<td>% 1st Class</td>
<td>-0.31922</td>
<td>0.12939</td>
<td>-2.47</td>
</tr>
<tr>
<td>% 1st Cl Rst.</td>
<td>0.07448</td>
<td>0.11748</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Table 16.2: Fixed Effects Model Continued

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Std. Err.</th>
<th>t Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Rd Trp</td>
<td>0.04659</td>
<td>0.07898</td>
<td>0.59</td>
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<tr>
<td>Avg Dist.</td>
<td>-0.0002</td>
<td>4.65×10⁻⁵</td>
<td>-4.38</td>
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<tr>
<td>Avg Dist.²</td>
<td>-4.98×10⁻⁹</td>
<td>2.07×10⁻⁹</td>
<td>-2.41</td>
</tr>
<tr>
<td>% ½ Stop</td>
<td>-0.07147</td>
<td>0.09965</td>
<td>-0.72</td>
</tr>
<tr>
<td>% 1 Stop</td>
<td>-0.37552</td>
<td>0.03570</td>
<td>-10.52</td>
</tr>
<tr>
<td>% 1½ Stp</td>
<td>0.34387</td>
<td>0.17854</td>
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<tr>
<td>% 2 Stop</td>
<td>-0.59121</td>
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<td>Intntl Apt</td>
<td>-0.01766</td>
<td>0.04431</td>
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</tr>
<tr>
<td>City Tix</td>
<td>-1.8×10⁻⁵</td>
<td>2.64×10⁻⁷</td>
<td>-6.88</td>
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<tr>
<td>AL</td>
<td>-0.08173</td>
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<tr>
<td>BN</td>
<td>0.000232</td>
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</tr>
<tr>
<td>CO</td>
<td>0.22005</td>
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<tr>
<td>DL</td>
<td>0.00237</td>
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<tr>
<td>EA</td>
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<td>FL</td>
<td>0.06382</td>
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</tr>
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<td>NW</td>
<td>-0.47260</td>
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</tr>
<tr>
<td>PI</td>
<td>-0.11550</td>
<td>0.07775</td>
<td>-1.49</td>
</tr>
</tbody>
</table>

Table 16.3: Fixed Effects Model Continued
<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Std Err.</th>
<th>t Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC</td>
<td>-0.13083</td>
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</tr>
<tr>
<td>TI</td>
<td>0.26126</td>
<td>0.1471</td>
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<tr>
<td>TW</td>
<td>-0.12398</td>
<td>0.05540</td>
<td>-2.24</td>
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<tr>
<td>UA</td>
<td>0.27046</td>
<td>0.03762</td>
<td>7.19</td>
</tr>
<tr>
<td>WN</td>
<td>0.24878</td>
<td>0.09646</td>
<td>2.58</td>
</tr>
<tr>
<td>Iran Iraq</td>
<td>-0.05691</td>
<td>0.02986</td>
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</tr>
<tr>
<td>Gulf War</td>
<td>-0.00957</td>
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<tr>
<td>CO mrg TI</td>
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<tr>
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<tr>
<td>CO mrg FL</td>
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<td>AA mrg CL</td>
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</tr>
<tr>
<td>DL mrg PA</td>
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<td>0.05663</td>
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<tr>
<td>RC mrg HA</td>
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<td>0.15303</td>
<td>-0.06</td>
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Table 16.4: Fixed Effects Model Continued

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<th>Std Err.</th>
<th>t Value</th>
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<td>CO and EA</td>
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<td>CO pt Strike</td>
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<td>EA pt Strike</td>
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<td>Air Trf Strike</td>
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Table 16.5: Fixed Effects Model Continued
It is interesting to note that monopolies and duopolies (both dominant firm duopolies and symmetric duopolies) are not significantly different from each other. However, the signs of the parameters do support the tendency for markets with fewer firms to have higher price-cost margins.

The parameter estimate on the Herfindahl index is positive and statistically significant. Additionally, for markets with a dominant pair of firms, the Herfindahl index is positively related with price-cost markups. However, for markets with a dominant firm, the Herfindahl index is negative and insignificant. This seems to indicate that price competition is less aggressive in markets with a dominant pair of firms. The impact of increasing the Herfindahl index is larger for markets with a dominant pair of firms than the impact for markets with one dominant firm. This suggests that markets with a dominant firm may have more price competition than markets with a dominant pair and may be caused by predatory pricing among dominant firms. This "window-shade" pricing strategy involves the dominant firm slashing prices (lowering the Lerner index) in order to gain market share (increasing the Herfindahl index) and drive the weaker firm out of the market. Once the weaker firm leaves, the dominant firm is a monopolist and raises prices higher than their original levels. It should be noted, however, that a reduced form stuch such as this cannot truly ascertain whether strategies such as window-shade pricing are being employed. In order to reach a definitive conclusion, a structural model of dynamic oligopoly must be developed.

The two variables for multi-market contact are both positive and significant. Although the numbers may seem small, the parameter estimate on total sales in other markets cor-
responds to about a 2.5% increase in price over marginal cost evaluated at the mean. It appears then, that a firm's position in the national industry significantly affects its ability to raise price in any given market. This result supports (though certainly does prove) the notion that major carriers follow the "golden rule" of avoiding fare wars in certain markets in order to prevent other firms from initiating fare wars in other markets.

The variable for the total number of code-shared flights is negative and insignificant suggesting that code-sharing agreements do not lead to collusion. This result is consistent with previous studies that show that consumers may, in fact, benefit from code-sharing alliances.

The estimates for the control variables tend to be in the direction expected. Zero coupon tickets, by construction, will reduce the Lerner index dramatically. The variables for the number of stops tend to be negative, suggesting that requiring the passenger waste time lowers the price demanded, as expected. The percentage of coach restricted tickets is negatively correlated to price markups as expected. However, jumping from full fare coach to first class restricted does not significantly impact the Lerner index. This suggests that consumers feel that the extra amenities offered on first class travel just balance against the costs associated with fare restrictions.

As the percentage of first class tickets increases, the price cost margins decrease. This may seem counter-intuitive. To provide an explanation it is worth noting that demand for full fare first class tickets is probably very elastic. This would suggest that an airline can charge proportionally more for a first class ticket if they limit the quantity sold. Also, to
add an extra first class seat on a plane would require more than one coach or business class seat be removed and thus hurt revenues.

The variable IranIraq is significant and negative. This might suggest that oil price shocks during this war led to decreased profits due to increased fuel costs. However, the time-span of the Iran Iraq war also corresponds to a time when airlines over-invested in new planes. This excess capacity is also an explanation for why percentage markups were lower during this period. Another reason to be sceptical of the Iran Iraq dummy is that The Gulf War dummy is insignificant.

The merger dummies are mixed. It appears as if Northwest’s absorption of Republic led to higher profits for the absorbing firm. However, all other mergers had insignificant impacts. The CO and EA dummy is positive and significant, suggesting that the two firms may have colluded while they were under co-ownership.

The strike dummies are largely irrelevant. United’s pilots strike had a negative impact on firm profits, but other strikes, including the air traffic controller strike had no impact.

17. Conclusions

The nation’s policy makers have been very concerned about market power in the US airline industry ever since it was deregulated in 1978. After conducting a reduced form analysis of the impact of several market variables on percentage markups above marginal cost, this paper finds that government should be concerned about fare wars among dominant airline pairs and collusion among dominant pairs. The increase in the incentives to collude
caused by increased multi-market contact should also concern regulators (if the quote at
the beginning of the paper can be trusted, regulators currently do not consider multi-
market contact to be an issue). However policy makers need not worry about code-sharing
agreements, as they do not appear to bring prices up. These results are not conclusive,
however, and structural models of dynamic oligopoly need to be developed to address these
issues more completely.

The results of this paper by no means provide conclusive evidence of collusion and anti-
competitive practice. For instance, the effect on sales in other markets may just be caused
by brand loyalty to large, familiar carriers. To provide proof of collusion, fare war, and
"golden rule" strategies, a formal, structural model needs to be developed. This will be the
goal of future research.
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U.S. Airline industry’s static conduct on a market by market basis. Then an algorithm for transporting this procedure into a dynamic setting will be discussed.

It is assumed that a market (defined as a city pair route) can be in one of three states: perfect competition, collusion (or monopoly in the case of 1 firm), or Cournot oligopoly. The paper will first do a static analysis and estimate a demand equation with market conduct constraints to classify routes into each of the three categories. The attributes of the routes within each category will then be discussed in order to provide some insight as to what might influence the conduct of the market. Then, recognizing that collusive agreements can break down or build up over time, an iterative methodology is discussed for estimating which state particular routes are in at each point in time.

The primary data set used is the Department of Transportation’s Origin and Destination Data Bank 1 A (DB1A) which consists of a continuous one in ten sample of all tickets sold in the united states. The data is collected on a quarterly basis and the sample runs from 1979 I to 1992 IV. Previous research in collusion has either focused on industries at the national level, or focused on specific markets in a case study. This paper will address collusion on a market-by-market basis for the almost the entire United States (with only very small markets excluded). Thus, it will be broader than a case study but not so aggregated as to miss market-specific situations.

It is important to note that this study considers a market (route) to be neither the U.S. as a whole nor, as in most studies, a trip between origin and destination airports. Instead, a market is considered to be a trip between origin and destination cities. Having the market
defined as all flights in the U.S. leads one to the conclusion that regional carriers in different regions compete with each other. Since this is known not to be the case, it is prudent to conduct a more detailed analysis. However, defining a route by airports neglects the competition that airlines face from carriers that fly from different airports within the same city. For instance, if someone were to fly from Houston to Chicago, he or she would have four combinations of airport pairs to choose from: Bush Intercontinental/Chicago O'Hare, Bush Intercontinental/Chicago Midway, Houston Hobby/Chicago O'Hare, and finally Houston Hobby/Chicago Midway. If the flight were round trip, he or she would have four more airport combinations for the trip back. It is well known that United and American have a considerable share of flights from Bush Intercontinental to Chicago O'Hare because O'Hare is a hub for those two carriers. However, Southwest Airlines has a very large schedule of flights from Houston Hobby to Chicago Midway. Considering a route to be an airport pair would suggest that Southwest does not compete with United and American for flights between Houston and Chicago.

As a result, the markets defined in this paper will typically have more competition than the airport pair markets used in other studies. It seems appropriate that any paper attempting to find evidence of collusion would only state the existence of such evidence in the strongest of possible cases. This paper does, indeed find evidence of collusion for 436 out of a possible 3141 routes analyzed. However, the collusive routes had the lowest difference between marginal cost and price which suggest that truly collusive routes are characterized by natural monopoly and would face large economic losses if faced with competition. Routes
that test as being statically competitive actually have very large markups in price above marginal cost. It is thought that this result, rather than indicating true competition, highlights the inadequacies of static analysis in a dynamic market. One possible theory for the result is that carriers on these routes engage in collusion for large amounts of time and lapse into fare war periodically (either because of a breakdown in the collusive agreement or as a strategy to avoid detection). Such markets would not test as Cournot because prices are independent of shares. Also, the fare wars would drop average markups lower than a collusive model would suggest which would cause the collusive model to be rejected.

The paper is organized as follows: Section two summarizes previous airline market power research with special attention to a study by Brander and Zhang (1990). Section three discusses the data used while section four discusses estimation of the cost function and construction of the marginal cost estimates. Section five discusses the static model and its results. Section seven provides concluding remarks.

19. Previous Studies of Market Structure or Conduct in the U.S. Airline Industry

Using case study data from several markets. Brock (2000) notes three noticeable developments in the airline industry. First, the industry is becoming increasingly concentrated through mergers and through strategic alliances. Second, major firms are responding to smaller firms with increasing episodes of predatory pricing. And Third, tacitly collusive, non-competitive pricing strategies are becoming more prevalent. This paper will look for
concrete, econometric evidence of these phenomena by structurally modelling market structure and examining the possible causes of these structures.

Busse (2001) tests whether variables that describe a firm's financial condition affect the probability of that firm initiating a price war. She uses DB1A data from 1985 until 1992. Rather ingeniously, she uses Wall Street Journal Articles to identify when a price war occurs and which carriers initiated and participated in the price war. She models the probability of a firm entering a price war as being a function of demand (which she estimates separately), financial indicators and control variables. Her results indicate that firms whose financial measures are in the lowest third of the distribution are more likely by about 5 to 8 percentage points to start a price war. However, she assumes that the motivation for price war stems from deviations from collusive agreements and does not model fare wars as predatory pricing strategies. This paper assumes that markets that test as competitive in a static model are those markets that are closely linked to fare wars. The dynamic methodology proposed should be able to shed light on the nature and causes of such fare wars.

Alam et. al. (2001) use the directed divergence statistic (ddv) in order to examine parallel pricing strategies for carriers among airport routes. Carriers are found to have parallel pricing strategies if the ddv for the carrier pair is a stationary time series while divergent pricing strategies are characterized by a unit root. Using the Augmented Dickey Fuller test, they find that 36 out of the 57 ddv series where stationary - indicating symmetric pricing strategies between carrier pairs. Further, they find that symmetric pricing strategies
are more common in markets with fewer airlines, indicating that markets with few firms are characterized by collusion. This paper supports these conclusions, but very weakly. It is found in this analysis that collusive routes have 7 carriers on average while competitive and Cournot routes have 8 carriers on average.

Evans and Kessides (1994) use the fourth quarter version of DB1A from 1984 through 1988 to get data for the 1000 largest routes (airport pairs) in order to test the "mutual forbearance" theory. By regressing log price on a number of route and carrier characteristics and an index of multi-market contact, they find that fares are higher in city-pair markets served by carriers with extensive inter-route contacts. This result is consistent with the hypothesis that airlines live by the "golden rule;" i.e., that airlines do not engage in aggressive pricing strategies in markets for fear of what their competitors might do in other jointly contested markets. Although this paper does not explicitly deal with multi-market contact, those markets where collusion is suspected can be examined to determine if there is significant overlap between the competitors on collusive routes.

Armantier and Richard (2000) analyze a multi-market oligopoly model with entry and incomplete information on marginal costs. Given their parameter estimates, they simulate competition under the hypothetical agreement to share cost information. Such exchanges of information are standard when airlines enter into code-sharing agreements. They use DB1A data from the third quarter of 1993 on flights sold by United and American Airlines originating or terminating at Chicago O'Hare where the two are essentially duopolists. They utilize an interesting "structural inference" method to back out estimates of marginal
costs, given demand and the airline's production decisions. Their findings suggest that airline profits will go up by allowing exchanges of cost information while consumer surplus is largely unaffected and may even increase.

Brueckner (1997) constructs a model of international flights with a domestic and international carrier, each with a hub in the country of origin. Tests of this model show that code-sharing agreements benefit consumers. Brueckner points out that code-sharing agreements have a beneficial and a harmful effect. The beneficial effect is that code-sharing puts downward pressure on fares within the inter-lined markets while the harmful effects are that loss in competition within the inter-hub network (the network joining the hubs of the code-sharing partners) pushes prices upwards. Brueckner finds that the positive effects outweigh the negative effects.

19.1. Brander and Zhang

The major source of inspiration for this paper is a study by Brander and Zhang (1990). As such, it deserves a detailed discussion. Brander and Zhang calculates conjectural variations for a set of duopoly airline routes emanating from Chicago O'Hare airport where American and United Airlines have a hub. The model is

\[ \pi'_i = p + q_i p' \left( 1 + v^i \right) - c^i = 0 \]

where the index \( i \) indicates a particular carrier, \( \pi \) is profit, \( p \) is price \( c \) are marginal costs and \( v^i \) is the conjectural variations parameter which is assumed to be different for each carrier.
Under Cournot oligopoly, \( v^i = 0 \) for each firm. Under Bertrand (perfect competition in this paper) \( v^i = -1 \) for the firm with higher marginal cost and \( v^i > -1 \) for the other firm. Under cartel with identical costs, \( v^i = 1 \) for both firms. This leads to the equation estimated in the paper

\[
v^i = \left( p - c^i \right) \frac{\eta(Q)}{ps^i} - 1
\]

where \( \eta(Q) \) is the (positive) demand elasticity for the route and \( s^i \) is the share of firm \( i \) on the route.

The data is from the DOT's DB1A for the third quarter of 1985. Data are limited to non-stop coach tickets (excluding zero coupon) to and from Chicago O'Hare and 33 other endpoints. Marginal costs, like those used in this paper, are estimated from DOT's Form 41/T100 cost and production data using a linear cost function. Demand (or demand elasticity) is not estimated, but rather taken to be the national average from previous studies and is 1.6 for all routes in their basic specification, and 1.2 and 2.0 in other cases. Their results indicate that most routes are closer to Cournot than either Bertrand or cartel.

As previously stated, this paper is primarily motivated by the Brander and Zhang study. It differs, however, from the Brander and Zhang study in many ways:

- Brander and Zhang only examine routes emanating from Chicago O'Hare while this paper examines routes linking the 85 largest U.S. cities. The results from this paper should yield a better understanding of the U.S. airline industry as a whole.

- Brander and Zhang do not incorporate zero coupon tickets into the study. The use of
frequent flier programs should increase competition and the exclusion of zero coupon
tickets will ignore this competition. This paper includes zero coupon tickets (as well
as first class tickets) and, thus, should provide a more accurate representation of the
degree of competition.

- Brander and Zhang limit the study to non-stop coach service emanating from Chicago
  O'Hare. This seems to be an incredibly restrictive definition of the market. While
  United and American are very close to duopoly in markets defined in this manner, they
  are nowhere near duopolies when the market is defined to be any service emanating
  from Chicago, Illinois. Particularly by eliminating flights to and from Chicago Midway,
  the Brander and Zhang study ignores the Southwest effect (Southwest flies into and
  out of Chicago exclusively from Midway). Also, by eliminating flights with more than
  one stop, any competition from airlines with other hubs is ignored. For instance, it is
  quite common for people to fly out of or into Chicago by taking TWA and stopping
  at St. Louis (a hub for TWA). By focusing exclusively on non-stop tickets emanating
  from Chicago O'Hare, the Brander and Zhang study distorts the true competitive
  nature of the route. This paper defines a route to be all tickets sold to and from any
  pair of cities. By defining a route in this manner, all competing carriers are included
  in the analysis and the true level of competition will be accounted for.

- Brander and Zhang assume that demand elasticity is the same across routes. How-
  ever, different cities have different population demographics and it is unreasonable
  to assume that consumer preferences are identical across cities. In addition, certain
markets have different proportions of business versus leisure travel. It is likely that business travelers' preferences are different than those of leisure travelers. Using the same demand elasticity across routes introduces the possibility that routes are misclassified because the demand elasticity for that route is higher or lower than assumed. This paper recognizes the need for elasticity to vary by route and, as such, estimates a route specific demand function.

- Because Brander and Zhang use previous estimates of demand that did not also estimate route structure. As a result, the demand elasticity estimates are biased due to endogeneity. To see this, note that any market behavior that does not set price equal to marginal cost will have a supply decision that can be described as picking a certain point on the demand curve. Cartels and monopolies pick the point on the demand equation that maximizes market profits, Cournot oligopolies pick the point on the demand function that maximizes individual firm profits and so on. Thus, one cannot identify the demand equation without also identifying the supply decision. Since that supply decision depends critically on the elasticity of demand, one cannot identify demand without also identifying market structure. Particularly the estimated demand elasticity under competition should be very different from the estimated demand elasticity under collusion (similar for Cournot). The estimates of demand elasticity used in Brander and Zhang, and all similar structural variations approaches, are biased and cannot be trusted to yield accurate statements about market structure. This paper avoids this bias by structurally modelling market structure as well as demand
and then employing a likelihood ratio based test statistic to formally choose between models with different market structure equations.

20. The Data

20.1. Price Data

The DB1A data set includes a one in ten sample of all tickets issued from January 1979 through December 1992. These are aggregated so that all tickets with the same fare, airlines, plane changes and in the same quarter are grouped together. This leads to the loss of some potentially useful information such as date and time of day, flight number and equipment type. DOT further limits other information which appears on the actual ticket such as the complete fare class which includes restrictions on advance purchase, Saturday night stay, refundability and other restrictions. For this study, the only available fare information which is consistently given over time is whether the ticket is first class or coach and whether any restriction was placed on the ticket.

Before they eliminate information on time of day and date of travel, DOT uses this information to identify trip breaks, and consequently identifies the ultimate destination of travel. In some cases this can unambiguously be done: if there are two flight segments and the second ends where the first began, it is clearly a round trip ticket with the destination at the end of the first segment. If there are three trip segments things become less clear. The ultimate destination is most likely the place with the longest break. On the other hand, such a ticket could be associated with travel with both the city at the end of the
first segment and the city at the end of the second segment were destinations. Over the time period of the study, DB1A included tickets with up to 23 segments. In some cases these are listed simply as round trip tickets. Since the researcher has less information than DOT had to make judgements about what the ultimate trip purpose was, he or she is in no position to "fix" these tickets. Still, leaving multi-destination tickets in the sample would seriously compromise the study, since they represent sales in more than one market. In this study only tickets that can be clearly classified as either one-way or round trips with a single destination are used. Up to six total segments are allowed for the flight (a five stop, one-way ticket or a round trip ticket with two stops per leg of the trip). Including only one way and round trip tickets with no more than six total segments eliminates just over 1% of the total data.

Approximately four percent of all tickets in the DB1A data are zero coupon tickets. Zero coupon tickets are tickets where the listed price is zero. The primary sources of these tickets are the redemption of frequent flier miles and promotional activities by the airline or other companies (e.g. be the third caller and win an all expense paid vacations to Hawaii). Some of these tickets also represent free tickets given as an inducement for the consumer to voluntarily give up a seat on an overbooked flight. Previous research has excluded such tickets in the estimation of demand. However, the difference between marginal cost and price will be artificially large when these tickets are excluded and routes that are not collusive might be labelled as such by ignoring competition through frequent flier programs.

This paper includes zero coupon tickets by looking at the average price charged by a
carrier for a particular route/quarter pair. Using the average price includes zero coupon tickets into the analysis and also abstracts from the complications of differentiated product. Although it is more accurate to include ticket level data, this would not only eliminate zero coupon tickets \(\log 0 = -\infty\) but would introduce serious complications into the error term because the models assume a homogenous commodity while the individual tickets are clearly heterogenous.

For clarity, it is important to define what a coupon segment is. If a consumer purchases a ticket, the itinerary for that ticket contains "coupons" that correspond to flight numbers. If the itinerary involves a change in flight numbers, then there is a new "coupon." Consequently a coupon segment is that part of the itinerary in which the flight number remains the same. It is important to note that this does not correspond perfectly with a stop along the trip. If there is a stop in an itinerary that leads to a change in flight number, then that stop leads to a change in coupon segments. This can occur when the passenger changes plains, but also can occur when the passenger stays on the plane. However, if the passenger stays on the plane during the stop and the airline does not change flight numbers, then there is no new coupon segment. This disconnect between coupon segments and stops will lead to some error when estimating marginal costs and when estimating the impact of the number of stops on price.

20.2. Income Data

A data set containing quarterly observations on per capita income, and population has been compiled for the 85 largest U.S. cities. Per capita income for each route is calculated by
taking the population weighted average per capita income using both origin and destination
cities. The cities used for this analysis are listed in Tables 20.1 and 20.2.

20.3. Cost Data

DOT's Form 41/T300, the airline production data set, includes four inputs: labor; energy;
flight capital; and a residual category called materials that includes supplies, outside ser-
dices, and non-flight capital. The data set also includes two outputs: scheduled and a
non-scheduled revenue passenger-miles. Additionally, it includes two network traits: stage
length and load factor. Flight capital is described by four aircraft attributes: the average
size (measured in seats); the average age; and the separate proportions of aircraft in the fleet
that are jet powered or wide-bodied designs. The data set has complete information for the
14 largest U.S. air carriers that were operating at the time of deregulation, or their descen-
dant airlines. These carriers are American, Alaska, Eastern, Trans World, United, Braniff
International, Continental, Delta, Northwest, Western, Frontier, Piedmont, Republic and
Texas International. This provides nearly total coverage of scheduled air traffic by the early
1990's when the data set ends. This information is quarterly and air carrier specific. Rout-
tine data reporting for those carriers was well established at the time of deregulation.\textsuperscript{15} In
order to still use data from other carriers, they are grouped together and have a common
estimated cost function. This seems to be a reasonable way to proceed since the majority

\textsuperscript{15} New entrants could be added to this data set with some difficulty. However, these carriers have little
experience in providing the often burdensome reporting required by DOT Form 41. Noncompliance results
in virtually no sanctions. Consequently, new entrant data tend to be of significantly lower quality.
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Table 20.1: Cities and Airports Included in the Study
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Table 20.2: Cities and Airports Included in the Study Continued
of these carriers are of similar size. The version of the data described in more detail below provides the largest, cleanest data available on the production of US.-scheduled passenger air transport.\textsuperscript{16}

The procedure used in constructing the data set has changed considerably over the last decade. As more and more data sources become available, it will change further. One of the most significant factors in these changes has been an adaptation to the changes in the reporting requirements of DOT Form 41. In order to maintain comparability over time, data from all versions of Form 41 must be mapped into a single version. The latest significant revision, which occurred in 1987, eliminated many of the specific functional accounts that were used previously. The most significant changes occurred in the areas of labor, supplies and outside services. This latest version Form 41 data is the most restrictive in that it provides the least detail in most cases. In other instances, the 1985 revision of Form 41 data is somewhat more restrictive. However, many of these changes were in place for only a short period of time. Where the 1985 restrictions were most severe, the 1987-equivalent accounts were estimated. This occurred most seriously in the area of ground-based capital, where lease payments and capitalized leases had to be allocated between flight and ground capital. In other cases, it seemed reasonable to estimate 1985 accounts from the 1987 data provided. The objective was to maintain as much detail as possible in all areas of air carrier production.

The construction of the individual input and output categories is described below. In

\textsuperscript{16}The construction of the cost data was part of previous research involving Ila Alam, David Good and Robin Sickles.
cases where price and quantity pairs for a specific input or output are constructed, several subcomponents to that input or output are first constructed. These are then aggregated into a single input or output using a multilateral Tornqvist-Theil index number procedure. The result of this procedure is a price index (much like the consumer price index) that aggregates price information for commodities having disparate physical units. When total expenditures of the input or output category are divided by this price index, an implicit quantity index is produced.

20.3.1. Labor

The labor input was composed of 93 separate labor accounts aggregated into five major employment classes (flight deck crews, flight attendants, mechanics, passenger/cargo/aircraft handlers, and other personal). There is no attempt to correct for differing utilization rates since there is no information on the number of hours worked by the labor inputs. Expenditures in these five subcomponents are constructed from the expenditure data in DOT Form 41 Schedules P5, P6, P7, and P8.

Following the 1987 modification in Form 41, Schedules P7 and P8 were dramatically simplified, eliminating many separate expense accounts. Mechanics and Handlers appear as line 5 and 6 of the new Schedule P6. In order to be more compatible with the new Schedule P6, trainees and instructors were moved into the Other Personnel category. Flight attendant expense was calculated by subtracting accounts 5123 and 5124 from Schedule PS from line 4 (total flight personnel) on the new Schedule P6. Other labor related expenses—such as personnel expenses, insurance and pension, and payroll taxes—were included as labor
expenses. Since labor related expenses are provided on functional lines rather than on an employment class basis, they were allocated to each of the five employment groups on the basis of the expenditure share of that class. After the 1987 Form 41 changes, these three expenditure categories are provided on Schedule P6 as line 10, 11, and 12, respectively. The quarterly total head count of full-time equivalent personnel was found by averaging the monthly full-time personal plus one-half of the part-time employees over the relevant quarter.

In 1977, Schedule P10 was changed from a quarterly to an annual filing cycle. This meant that allocations of head counts into specific employment categories could not be done directly except for the fourth quarter of each calendar year. Instead, the distribution of head counts among the five labor groups was interpolated using the annual figures. The estimated head count in each group was found by multiplying the interpolated percentage by the calculated full-time equivalent head count for that quarter. In 1983, Schedule P10 was simplified. This simplification collapsed the handlers' category into a smaller number of separate accounts, but did not change the overall structure of the procedure.

Using the expense and head count information from above, the expense per person quarter and the number of person quarters were calculated. The multilateral Tornqvist-Theil price and quantity indices for the labor input were then derived.

20.3.2. Energy

The objective of the energy input category is to capture aircraft fuel only. Fuel that is used for ground operations and electricity are captured in the materials index. The energy input
was developed by combining information on aircraft fuel gallons used with fuel expense data per period. Aircraft fuel cost in dollars comes from Schedule PS, account 5145.1. Gallons of aircraft fuel is listed in Schedule T2, account Z921. This input has undergone virtually no change because these accounts remained substantially unchanged over the span of the data set. Even though only one component exists, the multilateral Tornqvist-Thiel index number procedure is used to provide normalization of the data.

20.3.3. Materials

The materials input is comprised of 69 separate expenditure accounts aggregated into 12 broad classes of materials or other inputs that did not fit into the labor, energy, or flight capital categories. Carrier-specific price or quantity deflators for these expenditure groups were unavailable. Instead, industry-wide price deflators were obtained from a variety of sources. The classification of these expenditure accounts are presented below along with the corresponding source for the price deflator.

In 1987, the modifications of Schedules P6 and P7 led to the elimination of hundreds of separate account categories. In most cases, this did not affect the ability to reconstruct the categories. The sources of information did change, however. Advertising expense, passenger food, and landing fees appear as line 22, line 6, and line 12 of the new Schedule P7, respectively. Expenses for aircraft maintenance materials, communications, insurance, outside services and outside maintenance and passenger and cargo commissions appear as line 17, line 23, line 24, line 25 + line 28, and line 26 + line 27 of the new Schedule P6. Ground equipment rental expense was line 31 of Schedule P6 minus account 5147 from
Schedule P5. Amounts for other supplies and utilities appear aggregated together as line 19 of new Schedule P6. These amounts were apportioned to the supplies and utilities categories using the carrier's average proportion in these groups over the 1981 through 1986 periods. Ground equipment that is owned was unaffected by the 1987 accounting change.

20.3.4. Flight Capital

The number of aircraft that a carrier operated from each different model of aircraft in the airline's fleet was collected from DOT Form 41, Schedule T2 (account Z820). Data on the technological characteristics for the approximately 60 types of aircraft in significant use over the period 1970 through 1992 were collected from Jane's All the World's Aircraft (1945 through 1982 editions).

First, for each quarter, the average number of aircraft in service was constructed by dividing the total number of aircraft days for all aircraft types by the number of days in the quarter. This provides a gross measure of the size of the fleet (number of aircraft).

In order to adjust this measure of flight capital, the average equipment size is also constructed. This was measured with the highest density single-class seating configuration listed in Jane's for each aircraft type. The fleet-wide average was weighted by the number of aircraft of each type assigned into service. In some cases, particularly with wide-bodied jets, the actual number of seats was substantially less than described by this configuration because of the use of first-class and business-class seating. The purpose was to describe the physical size of the aircraft rather than how carriers chose to use or configure them.

As a measure of fleet vintage, this study uses the average number of months used
since the FAA's type-certification of aircraft designs. The assumption is that technological innovation in an aircraft does not change after the design is type-certified. Consequently, the measure of technological age does not fully capture the deterioration in capital and increased maintenance costs caused by use. This measure does capture retrofitting older designs with major innovations, if these innovations were significant enough to require recertification of the type.

Finally, it is clear that conversion to jet aircraft was the major innovation during the 1960's and 1970's. While many carriers had largely adopted this innovation prior to the study period, it was by no means universal. Many of the local service airlines used turboprop aircraft as a significant portion of their fleets and this is controlled for by measuring the proportion of aircraft in the fleet that are jet powered. The proportion of wide-bodied aircraft was also calculated.

20.3.5. Output

The data set provides several measures of airline output and its associated characteristics. The most commonly used measure of carrier output is the revenue ton-mile. This data set provides this measure as well as measures of revenue output that are disaggregated into scheduled and nonscheduled output. Nonscheduled output includes cargo and charter operations. Further, measures of airline capacity are provided. This again can be disaggregated into scheduled and nonscheduled operations. Revenue and traffic data were available from DOT Form 41. These data allowed construction of price and quantities for seven different outputs produced by the typical airline. Again, the price per unit (passenger-mile or
ton-mile) of the relevant service as constructed by dividing the revenue generated in the category by the physical amount of output in that category. In cases where a carrier offered only one type of service (the convention was to call this "first class"), the service was redefined to be coach class. The reporting of revenue and traffic charter operations between cargo and passenger service was very sporadic. These two outputs were combined into a single category with passenger-miles converted to ton-miles, assuming an average weight of 200 pounds per passenger (including baggage). Changes in DOT Form 41 in 1985 led to the elimination of the distinction between express cargo and air freight. Consequently, these two categories were also collapsed. Three different price and quantity index pairs are generated. The first is total revenue-output and uses the multilateral Tornqvist-Theil index number procedure on all the revenue-output categories. The second used the Tornqvist-Theil index number procedure on the two passenger categories. The third results from the use of the index number procedure on mail, cargo and charter services.

The capacity of flight operations is also provided in this data set. This describes the total amount of traffic generated, regardless of whether or not it was sold. While it is possible to distinguish between an unsold coach seat and an unsold first-class seat (they are of different sizes), such distinctions are not logically possible in the case of cargo operations (mail and cargo could be carried in the same location). Consequently, the measure of airline capacity includes only three broad categories: first-class seat-miles flown, coach seat-miles flown, and nonscheduled ton-miles flown. With the change to T100 as the primary data base for airline traffic in 1990, carriers are no longer required to report available seat-miles,
revenue seat-miles, or revenues by the level of passenger service. Instead, these amounts are aggregated with revenues supplied as account 3901 on Schedule P1 after 1990.

The convention that passenger along with baggage is 200 pounds (one-tenth of a ton) is used to construct the nonscheduled ton-miles. Potential revenues that could be collected, if all services were sold, are constructed assuming that the prices for each of these categories remain the same as for output actual sold. In other words, the price for first-class revenue passenger-miles flown is imputed to first-class available seat-miles flown. The Tornqvist-Theil index number procedure is used to generate price and quantity pairs for total capacity output, passenger capacity output, and nonscheduled capacity output.

Two important measures of the carrier's network are also generated. The first is a passenger load factor. This is found by dividing revenue passenger-miles by available seat-miles. This measure is generally related to flight frequency with a lower number indication more frequent flights and consequently a higher level of service. Other definitions of load factor are possible, such as dividing the total passenger revenue collected by the total that would be collected were the planes flown full (derived from the passenger capacity output times passenger capacity price). Stage length also provides an important measure of carrier output. Generally, the shorter the flight, the higher the proportion of ground services required per passenger-mile and the more circuitous the flight (a higher proportion of aircraft miles flown is needed to accommodate the needs of air traffic control). This generally results in a higher cost per mile for short flights than for longer flights. Average stage length is found by dividing total revenue aircraft miles flown by total revenue aircraft
departures.

21. Constructing Marginal Cost Estimates

Individual carrier marginal costs are modelled with a Cobb-Douglas cost function:

\[
\ln \text{Cost} = \beta_1 \ln \text{RevPassM} + \beta_2 \ln \text{Enplanements} + \beta_3 \ln \text{CargoTM} \\
+ \beta_4 \ln \text{Cities} + \beta_5 \ln \text{LoadFactor} + \beta_6 \ln \text{PLabor} \\
+ \beta_6 \ln \text{P Fuel} + \beta_7 \ln \text{PMaterials} + \beta_8 \ln \text{PCapital} \\
+ \sum_{i=1}^{n\text{airlines}} \delta_{\text{airline}_i}
\]

The model estimates a scale elasticity of 1.0182 which is not statistically significantly different from 1 at conventional significance levels. The model, while simple, fits well (R^2 = .9956), is globally regular and provides a great deal of information about marginal costs. RevPassM are revenue passenger miles, or the sum of the miles traveled by paying passengers. Enplanements are the sum of the passengers on all flights. (A passenger who is on a flight is not considered to have enplaned if the flight involves a stop. If their itinerary requires that they change flights then a second enplanement would occur for that trip.) CargoTM are the number of cargo ton miles on a flight. Cities provides a measure of the network size for a carrier. Caves Christensen and Tretheway (1984) suggest that this is an important reason why airline costs differ. As the number of cities increases, the density
of traffic on the carriers network, holding number of passenger miles constant, tends to decrease. Incorporating LoadFactor into the model allows us to consider changes in revenue passenger miles increase, while holding the number of available seat miles constant. One would expect that increasing revenue passenger miles while holding available seat miles constant would have a very low cost since it involves simply filling up an otherwise empty seat.

With these estimates carrier specific marginal cost for the passenger’s flight can be calculated as

\[
\begin{align*}
\text{Terminal Costs} &= MC_{\text{enplanements}} \\
\text{Per Mile Cost} &= MC_{\text{revpasmi}} \\
\text{Total Segment Cost} &= MC_{\text{enplanements}} + MC_{\text{revpasmi}} \cdot \text{miles flown}
\end{align*}
\]

Marginal cost is carrier and time specific. For multi-segment trips, the cost of a particular itinerary is estimated by the sum of the cost for the individual trip segments.

\[
\text{Total Itinerary Cost} = \sum_{j=1}^{n\text{segs}} \text{Total Segment Cost}_j
\]

The cost estimates show growth rates that are on average slightly higher than those generated by SIFL. Between 1971-1 and 1992-4 there is an estimated 71.6% increase for a 500 mile trip and an 86.4% for a 1000 mile trip. It is important to mention that these estimates
were based on data for the entire U.S. system and not for specific city-pair routes. Cost data from individual routes is simply unavailable. The marginal cost estimates derived from this national data are clearly not as accurate as one would hope. However by incorporating information on the specific number of enplanements, and the specific distance of particular flights, the marginal cost estimates should be as accurate as possible. As a defense of these estimates it should be pointed out that they correspond very well with the SIFL.

It is important again to bring up the distinction between enplanements, stops, and segments. An enplanement occurs when a passenger boards a plane, a stop occurs when a plane carrying the passenger lands at an airport and a change in segment occurs when a person encounters a new flight number. The marginal cost estimates are for enplanements because the cost data is measured in enplanements. Ideally, the costs would be measured in stops because there is a large cost associated with each stop, regardless of whether the passenger boarded a new plane. Also, ideally the price data would be broken down by stops because the passenger should regard any stop as an inconvenience, not just stops that involved a change in flight number. However, it is broken down by segments. When imputing the marginal cost of any given flight using DB1A data the best proxy for an enplanement is the coupon segment. There will be some over-estimation when imputing costs from DB1A using cost data because some changes in segment occur without an enplanement. However there will also be some under-estimation because when using the cost data because some stops where no flight number changed will not be counted as an enplanement. Again, however, the resulting cost estimates do correspond with the SIFL.
22. The Model

For each route, demand is assumed to be Cobb-Douglas. That is, for route, $j$, and carrier, $i$, in quarter, $t$, market demand may be written as

$$Q_{jt} = e^{a_j p_{ijt}^{\beta_{1j}} p_{jt}^{\beta_{2j}} l_{jt}^{\gamma_j}} \prod_{q=1}^{3} \exp \left( q r_{q} \sigma_{q} q \right) \varepsilon_{ijt}$$

$$\ln Q_{jt} = \alpha_j + \beta_{1j} \ln p_{ijt} + \beta_{2j} \ln p_{jt} + \gamma_j \ln I_{jt} + \sum_{q=1}^{3} \sigma_{q} q r_{q} + \ln \varepsilon_{ijt} \quad (22.1)$$

where $p_{ijt}$ is the average price charged by carrier $i$ on route $j$ at time $t$, and $l_{jt}$ is the population-weighted average per capita income for the two cities in the route. $\bar{p}_{jt}$ is the average price of all other routes and is used as a price index. The demand for tickets on route $j$ is allowed to shift if the price on route $j$ changes relative to the average price of other routes. Own price elasticity is assumed to be negative ($\beta_{1j} < 0$) and flights are assumed to be normal goods ($\gamma > 0$). The $\varepsilon_{ijt}$ are assumed to be i.i.d log-normal.

There are usually several carriers flying on any particular route which implies the set of data for a route is a panel. However, the assumption of a market demand rather than a carrier specific demand forces the assumption of the law of one price. Consequently, panel estimation techniques such as random and fixed effects are not relevant. It may seem more likely that carriers sell a differentiated product which would lead to carrier specific demands. However, the profit maximizing condition for a collusive differentiated product market is too complex to be estimated structurally.
22.1. Profit Maximizing Conditions and Estimated Equations

It is assumed that each route can exhibit three possible states of market conduct: perfect competition, Cournot competition, or collusion. If the route is perfectly competitive then the first order condition for profit maximization is

\[ p_{ijt} = c_{ijt} \]

\[ \ln p_{ijt} = \ln c_{ijt} \]  \hspace{1cm} (22.2)

where \( c_{ijt} \) is carrier \( i \)'s marginal cost on route \( j \) in time \( t \) (the average itinerary cost for each carrier on route \( j \)). If the market is Cournot oligopolistic then each firm's total revenue can be written as \( TR_{ijt} = p_{ijt}q_{ijt} \) where \( \sum_i q_{ijt} = Q_{jt} \). The first order condition of profit maximization is then

\[ p_{ijt} + q_{ijt} \frac{\partial p_{ijt}}{\partial q_{ijt}} = c_{ijt} \]

\[ p_{ijt} + q_{ijt} \frac{\partial p_{ijt}}{\partial Q_{jt}} = c_{ijt} \]

\[ p_{ijt} + q_{ijt} \frac{\partial p_{ijt}}{\partial Q_{jt}} \left( \frac{Q_{jt} p_{ijt}}{p_{ijt} Q_{ij}} \right) = c_{ijt} \]

\[ p_{ijt} + \frac{1}{\beta_{ij}} \left( \frac{q_{ijt}}{Q_{ij}} \right) p_{ijt} = c_{ijt} \]

\[ p_{ijt} \left( 1 + \frac{1}{\beta_{ij}} s_{ijt} \right) = c_{ijt} \]

\[ \ln p_{ijt} = \ln c_{ijt} - \ln \left( 1 + \frac{1}{\beta_{ij}} s_{ijt} \right) \]  \hspace{1cm} (22.3)
where $s_{ijt}$ is carrier $i$'s share in route $j$ at time $t$. Finally, if the market is collusive (or if the market is, in fact a monopoly), the revenue for the market is $TR_{jt} = p_{ijt}Q_{jt}$. The first order condition for profit maximization is

$$p_{ijt} + Q_{ij} \frac{\partial p_{ijt}}{\partial Q_{jt}} = c_{ijt}$$

$$p_{ijt} + Q_{ij} \left( \frac{\partial p_{ijt}}{\partial Q_{jt}} \frac{p_{ijt}}{Q_{jt}} \right) = c_{ijt}$$

$$p_{ijt} \left( 1 + \frac{1}{\beta_1} \right) = c_{ijt}$$

$$\ln p_{ijt} = \ln c_{ijt} - \ln \left( 1 + \frac{1}{\beta_1} \right) \quad (22.4)$$

and the requirement $\beta_1 < -1$ must hold because marginal revenue would otherwise be negative (recall that monopolies will never produce in the inelastic range of demand).

In Brander and Zhang (1990) and other conjectural variations studies, a demand equation is estimated without making an assumption about market structure. The resulting demand elasticity is then used to check which of the three possible states fits best (either by hypothesis test or by minimizing marginal revenue minus marginal cost). For instance, once the demand elasticity has been estimated, a structural variations model of the form:

$$p \left( 1 + \frac{1}{\beta \theta} \right) = mc$$

is used. Hypothesis tests on the parameter $\theta$ are used to draw conclusions on market structure. This paper takes a different, more formal approach. Taking the demand equation, 22.1, and the equations for profit maximization, 22.2, 22.3, and 22.4, three separate, two-
equation models are formed:

\[
\ln Q_{jt} = \alpha_{jc} + \beta_{1jc} \ln p_{ijt} + \beta_{2jc} \ln p_{jt} + \gamma_{jc} \ln I_{jt} + \sum_{q=1}^{3} \sigma_{qjc} q_{trq} + \ln \varepsilon_{ijt}
\]

\[
\ln p_{ijt} = \ln mc_{ijt} + \eta_{ijt} \quad \beta_{1jc} < 0, \gamma_{jc} > 0
\]

\[
\ln Q_{jt} = \alpha_{jc} + \beta_{1jc} \ln p_{ijt} + \beta_{2jc} \ln p_{jt} + \gamma_{jc} \ln I_{jt} + \sum_{q=1}^{3} \sigma_{qjc} q_{trq} + \ln \varepsilon_{ijt}
\]

\[
\ln p_{ijt} = \ln mc_{ijt} - \ln \left(1 + \frac{1}{\beta_{1jo}} s_{ijt}\right) + \eta_{ijt} \quad \beta_{1jo} < 0, \gamma_{jo} > 0
\]

\[
\ln Q_{jt} = \alpha_{jc} + \beta_{1jc} \ln p_{ijt} + \beta_{2jc} \ln p_{jt} + \gamma_{jc} \ln I_{jt} + \sum_{q=1}^{3} \sigma_{qjc} q_{trq} + \ln \varepsilon_{ijt}
\]

\[
\ln p_{ijt} = \ln mc_{ijt} - \ln \left(1 + \frac{1}{\beta_{1jm}} \right) + \eta_{ijt} \quad \beta_{ij} < -1, \gamma_{j} > 0
\]

where the subscripts \(c\), \(o\), and \(m\) stand for competition, oligopoly (Cournot), and monopoly (collusion) respectively.

So every route \(j\) is associated with three systems of equations. These pairs of equations are estimated using weighted two-stage non-linear least squares where the weights are the total number of tickets sold by carrier \(i\) in market \(j\) at time \(t\) (except for the competitive model which is estimated by substituting marginal cost for price in the demand equation and estimating by weighted OLS).

The conjectural variations approach ignores the interaction between demand elasticity and market structure. One cannot hope to identify demand elasticity without controlling for
market structure. Additionally, the conjectural variations approach ignores the link between demand elasticity and shares that exist in Cournot markets. By structurally modelling and jointly-estimating demand and market structure, such bias in the demand elasticity is removed.

22.2. Model Selection Test

Once the models have been estimated the issue of which model to choose must be addressed. If these models were nested within each other, then a simple likelihood ratio test could be used. However, the models are not nested within each other. They are, in fact, strictly non-nested models. To see this, recall that the only difference in the models are the definitions of marginal revenue. Thus, the only ways for any two of the models to be equivalent are:

competitive \(=\) collusive: \(p_{ijt} = p_{ijt} \left( 1 + \frac{1}{\beta_{ij}} \right)\)

\(\iff \beta_{ij} = -\infty\)

competitive \(=\) Cournot: \(p_{ijt} = p_{ijt} \left( 1 + \frac{1}{\beta_{ij}} s_{ijt} \right)\)

\(\iff \beta_{ij} = -\infty \text{ or } s_{ijt} = 0 \forall i, t\)

Cournot \(=\) collusive: \(p_{ijt} \left( 1 + \frac{1}{\beta_{ij}} \right) = p_{ijt} \left( 1 + \frac{1}{\beta_{ij}} s \right)\)

\(\iff s_{it} = 1 \forall t \text{ and } \# \text{ carriers} = 1\)
It is not reasonable to assume that demand is ever infinitely elastic nor is it reasonable to assume that the shares of all firms in the market are zero. It may be reasonable to have an actual monopoly (share equals one). However, with this paper's broad definition of a market combined with the fact that the cities in the study are large cities, it so happens that no true monopolies appear for the entire duration of the data. Consequently, the competitive, Cournot, and collusive models never overlap.

22.2.1. Likelihood Ratio Based Test for Non-Nested Models.

Note, however, that the model

\[
\ln Q_{jt} = \alpha_{jc} + \beta_{1jc} \ln p_{ijt} + \beta_{2jc} \ln \bar{p}_{jt} + \gamma_{jc} \ln I_{jt} + \sum_{q=1}^{3} \sigma_{qjc} q \tau_{q} + \ln \varepsilon_{ijt}
\]

\[
\ln p_{ijt} = \ln m c_{ijt} - \delta_{1j} \ln \left(1 + \frac{1}{\beta_{1j}}\right) + \delta_{2j} \ln \left(1 + \frac{1}{\beta_{1j}} s_{ijt}\right) + \eta_{ijt}
\]

is equivalent to the competitive model if \(\delta_{1j} = \delta_{2j} = 0\), is equivalent to the cournot model if \(\delta_{1j} = 0, \delta_{2j} = 1\) and is equivalent to the collusive model if \(\delta_{1j} = 1, \delta_{2j} = 0, \beta_{1} < -1\).

This "supermodel" nests all three market structures.

One may be tempted to estimate this supermodel and construct likelihood ratio tests with a null that the supermodel is more likely than the competitive, Cournot, or collusive models. However, since it is surely the case that none of the markets are actually competitive, Cournot, or collusive, it is likely that none of the three models will be more likely than the supermodel.

Yet, the purpose of classifying markets into competitive, Cournot, or collusive is not to
make the claim that these markets are truly in any state. Rather it is to determine which of the states most closely resembles the true nature of the market. Testing any of the three models against the supermodel is not conducive to the purpose of the paper.

Fortunately, Vuong (1989) developed a simple likelihood ratio based test for strictly non-nested models that are themselves nested within a larger model. He also shows that this test is asymptotically distributed as a standard normal.

Consider two models with conditional densities \( f(y|z; \theta) \) and \( g(y|z; \gamma) \) that are both nested within a larger model with true conditional density \( h^0(y|z) \). Under some general regularity assumptions (not requiring i.i.d disturbances) and under the null, \( H_0 \), that \( f(\cdot|\cdot) \) is equivalent to \( g(\cdot|\cdot) \) and the alternatives, \( H_f : f(\cdot|\cdot) \) is more likely and \( H_g : g(\cdot|\cdot) \) is more likely, the following holds

\[
H_0 \quad : \quad E^0 \left[ \log \frac{f(Y_t|Z_t; \theta_\ast)}{g(Y_t|Z_t; \gamma_\ast)} \right] = 0
\]

\[
H_f \quad : \quad E^0 \left[ \log \frac{f(Y_t|Z_t; \theta_\ast)}{g(Y_t|Z_t; \gamma_\ast)} \right] > 0
\]

\[
H_g \quad : \quad E^0 \left[ \log \frac{f(Y_t|Z_t; \theta_\ast)}{g(Y_t|Z_t; \gamma_\ast)} \right] < 0
\]

where \( \theta_\ast \) and \( \gamma_\ast \) minimize the Kullback-Leibler (1951) Information Criterion

\[
\theta_\ast = \arg \min_{\theta} E^0 \left[ \log h^0(y|z) \right] - E^0 \left[ \log f(y|z; \theta) \right]
\]

\[
\gamma_\ast = \arg \min_{\gamma} E^0 \left[ \log h^0(y|z) \right] - E^0 \left[ \log g(y|z; \gamma) \right]
\]

The indicator \( E^0 \left[ \log f(Y_t|Z_t; \theta_\ast) \right] - E^0 \left[ \log g(Y_t|Z_t; \gamma_\ast) \right] \) is unknown, but it can be con-
siently estimated by $\frac{1}{n}$ times the likelihood ratio statistic. Vuong goes on to show that, under regularity conditions

\[
\text{under } H_0 : \ n^{-1/2} LR_n \left( \hat{\theta}_n, \hat{\gamma}_n \right) / \hat{\omega} \xrightarrow{D} N(0,1)
\]

\[
\text{under } H_f : \ n^{-1/2} LR_n \left( \hat{\theta}_n, \hat{\gamma}_n \right) / \hat{\omega} \xrightarrow{a.s.} +\infty
\]

\[
\text{under } H_g : \ n^{-1/2} LR_n \left( \hat{\theta}_n, \hat{\gamma}_n \right) / \hat{\omega} \xrightarrow{a.s.} -\infty
\]

where

\[
\hat{\omega}^2 = \frac{1}{n} \sum_{i=1}^{n} \left[ \log \frac{f(Y_i|Z_i; \hat{\theta})}{g(Y_i|Z_i; \hat{\gamma})} \right]^2 - \left[ \frac{1}{n} \sum_{i=1}^{n} \log \frac{f(Y_i|Z_i; \hat{\theta})}{g(Y_i|Z_i; \hat{\gamma})} \right]^2
\]

is the variance of the likelihood ratio statistic. This provides a simple directional test: reject $H_0$ in favor if $n^{-1/2} LR_n \left( \hat{\theta}_n, \hat{\gamma}_n \right) / \hat{\omega} > c$, reject $H_0$ in favor of $H_g$ if $n^{-1/2} LR_n \left( \hat{\theta}_n, \hat{\gamma}_n \right) / \hat{\omega} < -c$ and fail to reject $H_0$ if $\left| n^{-1/2} LR_n \left( \hat{\theta}_n, \hat{\gamma}_n \right) / \hat{\omega} \right| \leq c$. It is this test that is used to select between models and classify market states.

22.2.2. The Problem With Marginal Revenues Based Selection

One might think that since the marginal revenues implied by competition, Cournot or collusion are ordered, that an order in the testing procedure would be appropriate. In particular, if the competitive model is closer to the truth than the Cournot model, how could the collusive model possibly be closer to the truth than the competitive model? This line of thinking suggests a two stage test: first test competition against Cournot and then test those models for which Cournot is closest against collusion.
However, this line of thinking makes the same mistake that conjectural variations models make - that an ordering of marginal revenues is the only implication of market structure. In fact, there are two conditions implied by competitive, Cournot and collusive models:

1. $p_c < p_o < p_m$

2. $p_c, p_m \perp s$ while $p_s \not\perp s$

The second implication is very important when firms have different marginal costs (as is the case in the U.S. airline industry). In the conjectural variations approach, what would one do if it were discovered that prices were much closer to Cournot than to monopoly or competition, but it was discovered that prices move independently of market shares?

The formal testing procedure advocated in this paper deals with this second implication. A model is declared closest to the truth if the combination of implications 1 and 2 implied in any model are more likely than the other models. It is therefore, very possible that the competitive model will win against the Cournot model while the collusive model wins against the competitive model.

22.2.3. Final Model Selection Algorithm

So, the final algorithm for selecting the model which best describes the market is:

1. Estimate the competitive, Cournot, and collusive models.

2. Calculate the likelihood ratio based test statistic for competitive versus Cournot, Cournot versus collusive and competitive versus collusive and denote these tests $t_{cc}$,
$t_{cm}$, and $t_{qm}$ respectively. (for clarity, the most competitive model is assumed to have
distribution $f(\cdot | \cdot)$ and the least competitive model is assumed to have distribution
$g(\cdot | \cdot)$)

3. If $t_{co} > c$ and $t_{cm} > c$ then competition wins against both Cournot and collusion and
the market is declared competitive.

4. If $t_{co} < -c$ and $t_{qm} > c$ then Cournot wins against both competition and collusion
and the market is declared Cournot oligopolistic.

5. If $t_{co} < -c$ and $t_{cm} < -c$ then collusion wins against both competition and Cournot
and the market is declared collusive.

6. In all other cases declare the market "inconclusive"

22.3. Results

The likelihood ratio based test yields 436 routes that can be classified as collusive, 838 that
can be classified as Cournot and 1852 that can be classified as competitive. Fifteen routes
could not have a clear decision made on which model fit best and are labeled inconclusive.

Summary statistics for each state are listed in table 22.1.\footnote{There are several very small carriers that cannot reasonably be considered competitors because so few tickets are sold. To construct the Avg \# of firms variable, any carrier/quarter observation that had less than 100 tickets sold was eliminated. Since this is a one in ten sample, all carriers used to calculate this variable had approximately 1,000 or more tickets sold in a quarter. This explains why inconclusive routes have no carriers.}
<table>
<thead>
<tr>
<th></th>
<th>Collusive</th>
<th>Cournot</th>
<th>Competitive</th>
<th>Inconclusive</th>
</tr>
</thead>
<tbody>
<tr>
<td># Routes</td>
<td>436</td>
<td>838</td>
<td>1852</td>
<td>15</td>
</tr>
<tr>
<td>Avg. $\beta_{1j,competitive}$</td>
<td>-2.4268</td>
<td>-1.8545</td>
<td>-1.3307</td>
<td>-0.4976</td>
</tr>
<tr>
<td>Avg. $\beta_{1j,Cournot}$</td>
<td>-9.7988</td>
<td>-1.7925</td>
<td>-9.9250</td>
<td>-2.1708</td>
</tr>
<tr>
<td>Avg. $\beta_{1j,competitive}$</td>
<td>-4.5020</td>
<td>-4.5375</td>
<td>-7.1651</td>
<td>-3.6667</td>
</tr>
<tr>
<td>Avg. Price</td>
<td>318.59</td>
<td>637.75</td>
<td>473.84</td>
<td>325.31</td>
</tr>
<tr>
<td>Avg. Cost</td>
<td>242.77</td>
<td>153.42</td>
<td>239.31</td>
<td>283.16</td>
</tr>
<tr>
<td>Avg. Markup</td>
<td>23.80%</td>
<td>75.94%</td>
<td>49.37%</td>
<td>12.96%</td>
</tr>
<tr>
<td>Avg. Sales/Firm</td>
<td>854,000</td>
<td>4,770,400</td>
<td>805,542</td>
<td>50,492</td>
</tr>
<tr>
<td>Avg. # of Tickets</td>
<td>2847</td>
<td>5440</td>
<td>2573</td>
<td>161</td>
</tr>
<tr>
<td>Tot. # of Obs.</td>
<td>126,474</td>
<td>284,881</td>
<td>531,156</td>
<td>3,497</td>
</tr>
<tr>
<td>Avg. Tix/Route</td>
<td>825,850</td>
<td>1,849,300</td>
<td>737,940</td>
<td>37534</td>
</tr>
<tr>
<td>Avg. # of Firms</td>
<td>7.3889</td>
<td>8.1943</td>
<td>7.9683</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 22.1: Results of Static Model

Notice that the estimated demand elasticity changes by market structure. This contrasts with the conjectural variations approach which assumes that demand elasticity can be determined independently of market structure. In a truly competitive market, supply does not depend upon demand. However, in any other market structure, quantity supplied depends crucially upon demand. The demand elasticity for collusive routes is highest at -4.5. The elasticity of demand for Cournot markets is next highest at -1.8 with competitive markets the least elastic with an estimated elasticity of -1.33.

Of particular interest is the average markup above marginal cost for each market state. Notice that models that test as collusive have much lower markups than other markets. This seems counter-intuitive. Remember, however, that comparing markups across routes does not serve as a check of the validity of the models. One must consider what the markups in each state would have been were there to be a change in structure. What can be said is that carriers take a conservative approach to collusion. Rather than collusion occurring in routes
where potential profit is highest, collusion tends to occur on routes where the lost revenue due to competition has the greatest chance of driving firms out. It is likely that these markets are naturally monopolistic markets where average costs are greater than marginal costs. Unfortunately, without truly route specific cost data, this cannot be confirmed.

Another counter-intuitive result is that markets that test as competitive have price-cost markups of almost 50%. Again, it must be remembered that these routes are not truly competitive. Rather, they test as being closer to competitive than any other model. This can occur when markups are closer to zero than demand models suggest and/or closer to zero than Cournot models suggest while also having prices that are orthogonal to market shares. One should be concerned about the possibility that some routes may have markups that are not closer to zero than Cournot models would suggest but are, instead, independent of market shares. It may be that some of these markets are acting as a constrained cartel - behaving collusively for long time periods, but collapsing into fare war often enough to bring down average price-cost margins in an attempt to prevent government detection and intervention. This hypothesis is bolstered by the fact that competitive markets actually have the lowest number of tickets per route. This issue can only be addressed by a dynamic model. Developing such a dynamic model will be the goal of future research.

Routes that test as Cournot have the largest difference between average price and average cost. This is not unreasonable since carriers have little incentive to risk detection and government intervention on routes that already yield high non-collusive profits.

There does not appear to be any serious relationship between the number of firms
servicing a route and the state of the market. Collusive markets have a smaller number of carriers on average, but this difference is less than one carrier.

23. Concluding Remarks

There have been many previous attempts at determining market power in the U.S. airline industry. Yet none have attempted to structurally model market behavior. This paper has provided a basis for structurally estimating alternative models of market structure and used a likelihood ratio based test to formally select which of the proposed models are more likely. The analysis finds that out of 3141 routes used in this paper, 436 can be declared closest to collusion, while 838 routes fit the non-cooperative Cournot oligopoly better and 1852 markets were closest to a model of perfect competition. The results of this static analysis are quite interesting because they indicate that monopoly routes have the lowest percentage markups on marginal cost - implying that truly monopolistic routes should be of least concern to those wishing to maximize consumer surplus. Another interesting result is that routes that test as competitive have relatively large markups. It may be that firms in this market are involved in a dynamically collusive agreement that involves periodic fare wars. If this were true, the static model would test as competitive even though prices are considerably higher than marginal cost. The goal of future research should be to develop a dynamic model of market structure that could be used to find evidence of such behavior.
Part IV

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