

A HEDONIC PRICE INDEX FOR AIRLINE TRAVEL

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Our research takes an exhaustive approach to measurement issues in price index construction for the BLS airfare index. We pursue a number of the objectives for dealing with the biases that the 1997 CPI Commission recommended and detail a protocol for data collection and analysis that can be replicated and can be enhanced by availability of additional data sources. We find an upward bias in the BLS airfare index over the period considered. However, because of issues of practicality and implementability of the methods we utilize in our analysis, the goals of the Commission recommendations remain illusive and problematic in being more broadly applied to other components of the CPI.

1. INTRODUCTION

Ideally, the Consumer Price Index (CPI) measures the price of a fixed market basket over time. The CPI has a wide variety of uses as both a measure of the overall inflation in the economy and as a cost of living index (COLI). The CPI Commission outlined several features of the CPI which tend to make it less useful as a COLI. The issues raised by the CPI Commission are discussed at length in Boskin *et al.* (1997, 1998) and Boskin and Jorgenson (1997). First, 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 toward commodities with lower price increases (substitution bias). Second, because price changes are considered only within outlets, the index does not allow for consumers to substitute away from higher priced outlets toward lower priced outlets for identical items (outlet substitution bias). Third, since the market basket is typically sparse in details about quality, the CPI does not always consider the

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possibility that price increases may be caused by unmeasured quality improvements in the items that constitute the fixed market basket that increase consumer welfare (quality change bias).

The CPI Commission concluded that changes in the CPI overestimated the change in the Cost of Living by about 1.1 percent per year. They estimated the portions of bias that could be attributed to substitution bias and outlet substitution at 0.4 and 0.1 percent per year. They also estimated the portion that could be attributed to failing to control for the quality of existing commodities and to incorporate new commodities at 0.6 percent per year. The commission concluded that impacts of this bias were far reaching since many government expenditure increases, most notably Social Security, are tied into the CPI. Consequently, the bias has led the federal government to overcompensate individuals for the cost of living, leading some to conclude this overcompensation has accelerated inflation as more dollars in benefits chase a fixed level of goods. The commission generated a number of recommendations. Among them were: (i) use hedonic statistical methods to adjust for quality change; (ii) reweight 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; and (vi) use new sources of data such as scanner data.

This paper describes the implications of implementing some of these recommendations in the context of one specific component of the CPI, domestic airline fares. To our knowledge, ours is the first paper to integrate so many of these recommendations simultaneously: re-weighting every period, hedonic models and the use of scanner-like data. We view the consumer’s market basket of airline travel commodities as composed of a number of alternative city-pair routes. The airline fares portion of the CPI is amenable to the CPI Commission’s recommendations because data sets of ticket sales already exist. In other industries, improved data collection may prove difficult because national level data collection requires cooperation that these firms are unlikely to willingly provide.

Based on the U.S. Department of Transportation’s (USDOT) origin and destination data (O&D) we estimate a quality-adjusted price index for airline fares using a hedonic price regression which includes quality characteristics as well as time dummies. From these estimates we are able to construct quality adjusted changes in price over time. Basing our adjustments on the O&D database is also useful in dealing with market basket composition issues. Because the weights consists of sales data, they can be adjusted as the quantities sold adjust. 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. Interregional comparisons can be made because the data collection techniques are the same across regions. Still there are some limitations: airline data are collected quarterly rather than monthly (making construction of a monthly airfare index difficult), smaller airlines tend to underreport and some information about fare class is

censored. Even so, the aviation O&D data have a much broader geographical coverage and longer time series than any other single source publicly available sales data series in any other industry of which we are aware.

The paper is organized as follows. In the next section we discuss developments in the literature on price indices and on specific problems with the construction of an air travel price index. In Section 3, we discuss the methods employed by the Bureau of Labor Statistics (BLS) to calculate the Consumer Price Index for Airfares. In Section 4, we present the construction of measurements for a number of fare characteristics and present their trends during the period of our study, 1979I–1992IV. In Section 5, we construct 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. Our final section presents results and provides concluding remarks.

2. SOURCES OF BIAS IN THE CPI: SUGGESTED CORRECTIONS AND THEIR IMPLICATIONS FOR THE AIRLINE PRICE INDEX

As we pointed out in the introduction, the CPI Commission concluded that changes in the Consumer Price Index overestimated the change in the Cost of Living by about 1.1 percent. The bias was attributed to three factors: the substitution bias, outlet substitution bias, and quality change bias (or new goods bias). Boskin *et al.* (1998) discuss the Commission findings and describe the sources of these biases in detail. They also discuss another type of bias that few have deemed important. This is a “when” bias (referred to in this paper as “intertemporal substitution bias”). The “when” bias occurs because price data tend to be collected during the week, whereas an increasing share of purchases are made on weekends and holidays. Many outlets even emphasize weekend sales.

The Commission's conclusions generated a large quantity of further research—both supporting and refuting the Commission's findings. Abraham *et al.* (1998) provide the BLS response to the CPI Commission's report and describe initiatives at the BLS that are intended to improve the accuracy of the CPI (some of which were enacted before the Commission's report). Pollak (1998) claimed that changing the CPI so that it could more accurately reflect a cost-of-living index was not possible without addressing very fundamental issues which still appear to be unresolved. Whose cost-of-living do we want to model? How can we deal with an economy in which the law of one price does not hold and consumers must search for the best price? What exactly is a good? Baker (1998) summarizes criticism of the CPI Commission's report. Among several issues, he asserts that several estimates of bias depend exclusively upon introspection and several other estimates are the result of either misinterpreting previous research or making dubious extrapolations from that research.

Possible bias in government inflation statistics is not just a concern in the United States and when the findings of the Boskin Commission were made public, the international community responded. In 1997 Statistics Canada published a joint study examining CPI bias in four other OECD countries (Australia, Canada,

France, U.K.) (Ducharme, 1997).¹ Referring to the international impacts of the report it states, “. . . in a number of countries it raised the awareness of the need to review formulae, improve underlying household surveys (make them more frequent and more comprehensive) and adjust for quality variation all goods and services, especially complex goods and services typically offered in the market place as bundles.” It goes on to state, “The five national statistical agencies agree that quality change is the most difficult and important problem in estimating the CPI . . . [A]ll feel that the only way to progress is by developing a research agenda and, with the help of other experts, to systematically analyze the effects of quality change on estimated prices.”

The BLS has implemented several changes in the construction of the CPI in order to improve the accuracy of the index. Some of the improvements came as a result of the CPI Commission’s report and some were already being contemplated. To address lower level substitution bias the BLS moved toward using a geometric mean instead of an arithmetic mean. To address upper level substitution bias the BLS began issuing alternative superlative indexes for comparison. Other changes were also made to ameliorate outlet substitution bias. To address quality change bias the BLS commissioned several studies to investigate how hedonic price functions might be used to control for changes in quality of items in the market basket. We discuss below how such hedonic approaches have been applied to other industries and why the airline travel index in particular could benefit from controlling for quality characteristics hedonically.

2.1. *A Brief Review of Hedonic Literature*

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 1960s (e.g. Ridker and Henning, 1967) and 1970s (Rosen, 1974). Hedonic indices were applied to computers in the mid 1980s (e.g. Triplett, 1984) and more recently information technology products in general (Triplett, 2004). Other markets whose prices were revalued using hedonic techniques include the medical field (Primont and Kokoski, 1990; Trajtenberg, 1990) and university education (Schwartz and Scafidi, 2000). To our knowledge, our development of a price index for airline fares via a hedonic price approach is new to the literature. For a clear and concise review of hedonic regression theory we suggest the reader review Quigley (1982). Armknecht and Ginsburg (1992) offer hedonic regressions as a way to address the issue of quality that arises when new products enter the market. Hedonic models not only help in estimating quality differences resulting from a change in characteristics. They also enhance the analyst’s information about the quality composition of services offered. Specifically, the models can identify those quality characteristics that provide the largest impacts on price.

Armknecht and Ginsburg (1992) 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.

¹The study also included an updated discussion of efforts in the United States to address the issues raised by the Boskin Report.

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, for example, field staff can pick the most appropriate substitute by the most important characteristics according to the appropriate order. Pakes (2003) furthers this line of thinking by directly comparing matched model indexes to hedonic indexes in the market for PCs.

Pakes (2008) cautions the researcher that imperfect competition prevents the hedonic coefficients from being accurately interpreted as the consumer's marginal willingness-to-pay. He makes this point with a hypothetical example involving medications that illustrates the problem of interpreting the derivatives of a hedonic price function as either willingness to pay derivatives or cost derivatives, since empirical estimates are essentially reduced form solutions formed from a complex equilibrium process. Pakes makes it clear, however, that losing the interpretation of hedonic coefficients derivatives of a hedonic price function as either willingness to pay derivatives or cost derivatives does not invalidate the use of hedonics to control for quality in a price index. Pakes' concern about the interpretation of hedonic coefficients involves situations where the commodity is defined too broadly. An example is one in which the consumers buying drug A are not the same consumers buying drug B. If one were to run a separate regression for each drug, and if the toxicity of drug B were to reduce over time, we would expect to see a negative parameter estimate for toxicity.

Using this line of reasoning the large number of customers shopping among the various characteristics of an airline ticket would validate the interpretability of hedonic coefficients. Parameter estimates in our analysis below thus retain their interpretation as measures of the marginal willingness to pay because airline travel is not so broad a service as to apply to completely different consumer groups. Airlines do have different marketing strategies for different groups of consumers (business versus leisure travelers, for example). However, these groups of consumers are not exclusive sets of consumers. An airline passenger who is traveling on business now will be traveling for leisure later. Someone who buys a first class ticket today may well buy a discount coach ticket tomorrow. It seems reasonable to assume, for example, that a first class ticket was bought when the premium for first class was sufficiently small and that a coach ticket was bought when the premium was too large. In Pakes' drug example, it is hard to conceive of a consumer buying the more toxic drug if the price were lower. However, we cannot think of any quality attribute associated with an airline ticket that consumers could not be induced to change through a sufficient change in price.

2.2. CPI Bias and Quality Issues in the U.S. Airline Industry

In this section we discuss how CPI bias might appear in the index for airline fares as well as discuss research into quality issues in the U.S. airline industry. It should be noted that the BLS airline fares index is not the only price index for airline fares. The Bureau of Economic Analysis (BEA) produces the consumer expenditure deflator for airline fares as part of the National Accounts Estimation and the Bureau of Transportation Statistics is now publishing the Air Travel Price Index (ATPI) based on a Fisher index. Lent and Dorfman (2005) conduct a

detailed comparison of the ATPI to the CPI for airfares and the BEA's expenditure deflator. The ATPI is not available prior to 1995 while the quality-adjusted index constructed here ends in 1992. Consequently there can be no direct comparison between the two indices. It should be noted that the Fisher index does not necessarily represent a lower bound for a COL index and, as such, may be subject to less substitution bias. 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).

Gordon and Griliches (1997) point out that some quality improvements are quite problematic when attempting to incorporate them into a price index because they represent an abatement of "bads" that also were not considered in the index. 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 we have not pursued is the directional distance function paradigm introduced by Färe *et al.* (1994) and recently utilized in the context of the impact of environmental "bads" on growth accounting by Jeon and Sickles (2004).

Although they did not construct a price index, Morrison and Winston (1995) calculated marginal valuations of quality characteristics via an airline choice model. The marginal value of an additional mile for travelers who accumulated 3,501 to 15,000 miles was estimated to be 13 cents while for travelers who accu-

mulated 15,001 to 80,000 miles it was 21.5 cents. They estimated the cost of restrictions on a discount flight via a binary, probit model of choice between unrestricted vs. restricted fares. Although there appeared to be no significant costs for the leisure travel the business traveler incurred some significant costs. Saturday night restrictions 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. They found that multimarket contact did have an effect on fares in the industry but that the effects were highly cyclical. When the economy is growing rapidly fares were higher where there was multimarket contact than where there was none. 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 (e.g. Perloff *et al.*, 2003). Even in the presence of collusion on prices, airlines might still compete along quality dimensions. An example is Continental competing with United in the Dallas–Fort Worth/Washington DC market, in which there is anecdotal evidence of price collusion, by allowing for more carry-on luggage space. United tried to implement a carry-on size limit. Continental sued United in order to stop the carry-on limits.²

A number of studies have found that the consumer has benefited from airline deregulation. Caves *et al.* (1987) showed that deregulation increased the passenger-mile productivity growth rate between 1.3 and 1.6 percent per year. Morrison and Winston (1995) highlighted a number of important benefits accruing to consumers: (1) fares were about 22 percent lower with deregulation; (2) a benefit of about \$10.3 billion per year resulted from the elimination of route restrictions and an increased use of hub-and-spoke networks; (3) the proportion of passengers with direct nonstop flights increased, even though passengers often had to take an indirect route associated with the hub-and-spoke network structure; and (4) passengers who had to change planes rarely had to change airlines due to increases in network size.

It should be noted, however, that the benefits of such innovations as the hub-and-spoke systems may be overstated due to longer travel time, longer flight segments, and longer waiting times for the flights themselves because of scheduling and because of congestion. Ground time has increased by five minutes regardless of distance traveled. It would seem, however, that the cost of increase travel time (\$2.8 billion per year in 1995) was more than offset by the benefit of hub-and-spoke systems (Morrison and Winston, 1995).

²Continental Airlines, Inc. v. United Airlines, Inc., 126 F. Supp.2d 962 (E.D. Va. 2001). Continental Airlines challenged a rule at Dulles Airport imposing limits on the size of carry-on baggage. The Association of Air Carriers serving Dulles had imposed the rule at the insistence of United Airlines. The court struck down the rule, finding that it was not justified by safety and efficiency concerns, and that United attempted to influence the standard-setting process in an anticompetitive manner in order to relieve it from competitive pressure from air carriers which permitted larger carry-ons. However, that decision has been vacated, citing “unique structure of Dulles,” and remanded for further proceedings. See Continental Airlines, Inc. v. United Airlines, Inc., 277 F.3d 499 (4th Cir. 2002). The parties have subsequently agreed to dismiss the case.

3. SIMULATING THE CURRENT BLS APPROACH FOR CONSTRUCTING AN AIRFARES CPI

The airline fares index is the largest component (61 percent) of the public transportation index. It accounts for 0.814 percent of the total CPI. The BLS selects approximately 850 observations for its airline fares index. All regularly scheduled commercial airline trips departing from airports in the 87 cities in the CPI are eligible for use in the index. When the city does not have a qualifying airport, the qualifying airport from the nearest city is designated as the point of departure. Reflecting the average pattern of trips from the USDOT's origin/destination survey, 2 percent are first class, 4 percent are full coach fare, and 94 percent are discounted coach fares. The origin/destination survey does not identify types of discount fares. Thus the BLS assumes that half of the discounted coach fares are the lowest available fare regardless of restrictions. The BLS assumes that the other half includes specific restrictions. The fare at the time of sampling is found in the SABRE reservation system. This is the same system that historically has been used by much of the travel industry, though its use has declined substantially over the last two decades. 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.

Below we more formally describe the process used by the BLS during our study period (1979 through 1992) and the new procedure that they used beginning in 1999. Since we are interested in evaluating the current procedure of BLS but must evaluate it using older data we construct price indices using both methods. The first method is used for comparison to historical indices. The second is used to identify the historical index had current procedures been used. Below we describe the historical procedure and then how it changed in 1999.

Step 1 (primary sampling): Conduct random price sampling for all items in the market basket. The market basket is a set of origin–destination–fare class triples in each Price Sampling Unit (PSU). The PSU is a county within one of the metropolitan areas which is covered by the Consumer Price Index for all urban consumers (CPI-U).

Step 2 (aggregation process pre-1999): Compute the Air Fare CPI

$$\frac{AFCPI_t}{AFCPI_{t-1}} = \sum_j s_j \left(\sum_i w_{ij} \frac{p_{ijt}}{p_{ijt-1}} \right)$$

where the subscript i represents the item in the basket, j represents the PSU and t represents the time period. Weights w_{ij} are obtained from the Consumer Expenditure Survey and weights s_j represent the fraction of sales which occur in PSU $_j$ compared to the entire U.S.

Step 2' (aggregation process post-1999): Compute the Air Fare CPI

$$\frac{AFCPI_t}{AFCPI_{t-1}} = \sum_j s_j \left(\prod_i w_{ij} \frac{p_{ijt}}{p_{ijt-1}} \right).$$

The difference between step 2 and step 2' is the use of arithmetic means prior to 1999 and geometric means after 1999 at the stage where price ratios are aggregated to the level of the PSU.

Implementation of these procedures is complicated by inadequate information on the appropriate market basket and the proper weights. Unfortunately, the only market basket and weights available from BLS are those currently used and they were constructed in 1998. Market baskets and weights for earlier years are unavailable because the BLS did not archive this data. Information on deeply discounted fares with corresponding restrictions thus was not available in many of the years that our study covers.³

4. DATA SOURCES USED TO COMPUTE A NEW QUALITY ADJUSTED AIRFARE PRICE INDEX

The CPI is best computed when the products under consideration are simple homogeneous commodities. This does not describe the air transport industry, particularly over our study period, because air travel takes place between many different origins and destinations over alternative paths and with differing levels of service. In this section we discuss several of the important dimensions of air travel and how they affect the price of travel through changes in quality. These issues fall into seven broad quality categories: network configuration, flight convenience, passenger amenity, airport and flight delay, ticket restrictions, yield management, and frequent flier programs (zero coupon tickets). These categories will at times overlap. In many cases our choice of study period, from 1979 through 1992 is both interesting and restrictive. It is interesting because many fare innovations and service quality changes occurred during this time period following the deregulation of the industry in 1978. It is restrictive because many of the data sets which would be useful to identify service quality changes do not span our study period.

4.1. *Network Configuration*

Prior to deregulation, airline networks were constructed on a piecemeal manner. Airlines were granted routes out of “public convenience and necessity.” This often led to rather inconvenient routing for passengers, particularly to small communities. Deregulation opened access to all routes and by 1982 airlines could serve whatever routes they wished. Airlines responded by developing hub-and-

³One possible way to deal with the lack of weights would be to use the market basket from 1998 while acknowledging that the basket and weights changed over time. An alternative approach would be to use fare mixes each quarter from the Origin and Destination Survey. 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 of the CPI. We settled on eliminating fare class information all together in constructing weights. This produced a series that was quite similar to the CPI and appeared to be a better approximation to the use of an obviously incorrect fare mix.

spoke networks, adding some destinations and dropping others. In our study we consider three hedonic characteristics of the airlines network configuration: the indirectness of routing, change of planes, and the number of airlines used to complete the trip.

Airlines find different network configurations useful because they allow for higher passenger densities on individual routes, potentially allowing the airlines to take 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 costs the airline very little). In a simple network involving five cities (one serving as the hub), the cities can be connected with at most one change of plane service with as few as four round trip flights. Connecting the cities together with a network providing nonstop service would require 10 round trip flights. Adding an additional city would require one more round trip flight with a hub-and-spoke network compared to five more round trip flights using direct flights only.

Because passenger time is valuable, indirect routing is a cost to the passenger. The cost increases when the indirect routing involves changes of planes through a congested hub. On the other hand, indirectly routed passengers often will accrue more frequent flyer miles than a directly routed passenger.

When an airline does not serve both the origin and destination or serves them only indirectly, passengers must take part of their trip on one airline and the remainder on at least one other airline (interlining). Passengers perceive a lower quality of service when interlined. Baggage will more likely be mishandled or misdirected, the distance between gates at the connecting airport is usually greater, and there is the increased likelihood of a missed connection.

We measure the network characteristics at the individual ticket level. Using the DB1A, we identify the origin and the ultimate destination as indicated by a trip break. Approximately 30 percent of trips involve one way tickets (no trip breaks), 65 percent are one way (one trip break at the destination), and the remaining 5 percent involve open jaw or multibreak tickets. In order to gain an understanding of the bulk of trips we limit our attention to either one way or round trip tickets and develop separate models for each. The changing pattern of these tickets is described in Figure 1. For each trip type, we identify the complexity of the trip from the DB1A at the ticket level. The travel itinerary allows us to measure the number of segments (changes of planes with the same carrier) required in the itinerary, the number of airlines that were used to provide service, and the number of changes required to a different airline (interlines). For each of these variables the higher the variable the lower the quality of service. Figure 2 displays the patterns of one way trips over the sample period while the patterns of round trip itineraries are shown in Figure 3. For one way tickets 28 percent of the tickets used more than one airline on a trip in 1979I. By 1992IV only 4 percent of the one way itineraries required that passengers interline. There is little change in number of segments over the study period. The pattern for round trip tickets is similar. In 1979I 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. There is a slight increase in the number of segments, indicating that while passengers were not decreasing the number of segments over the study period they were switching to

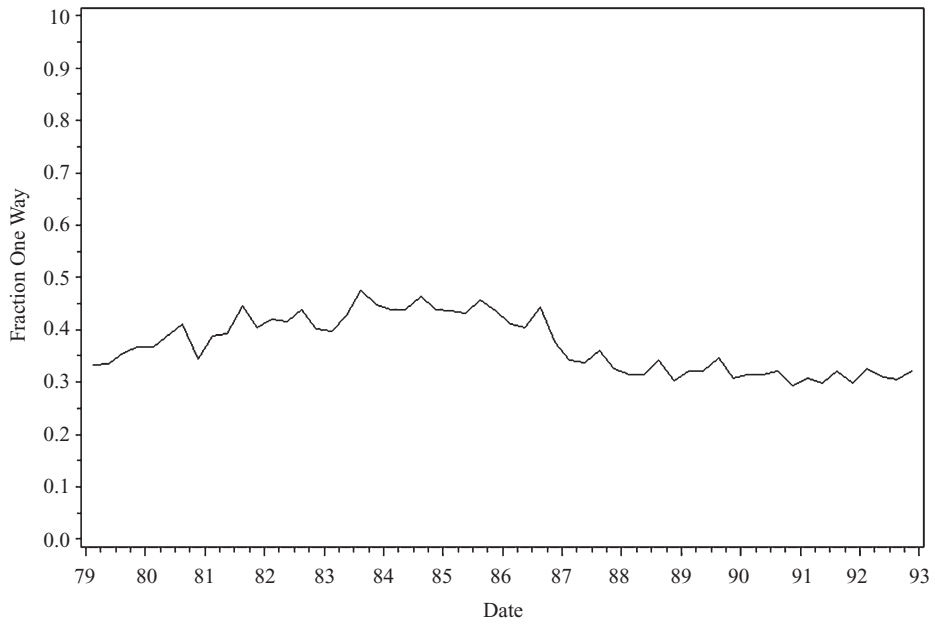


Figure 1. Fraction of One Way Tickets Sold

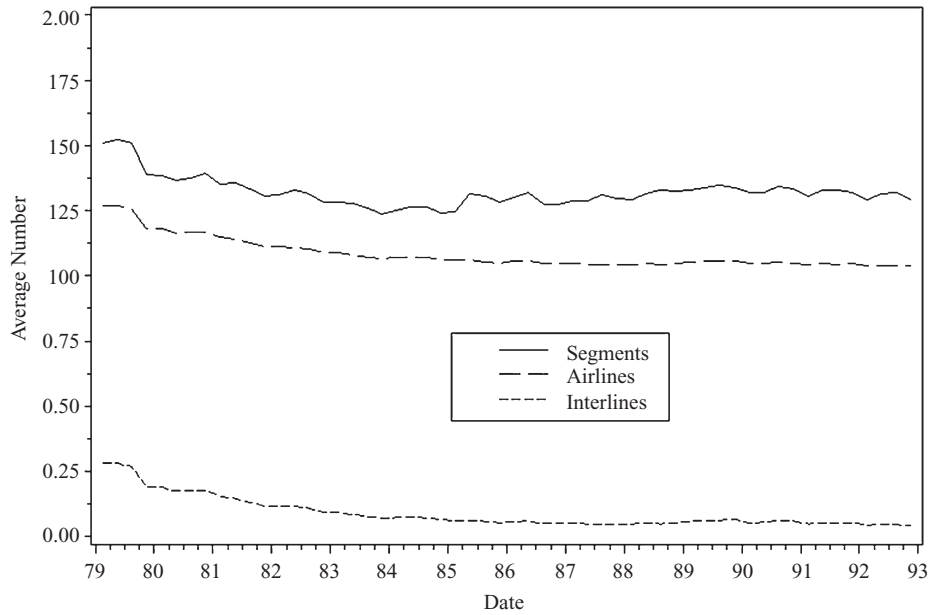


Figure 2. Patterns of One Way Itineraries

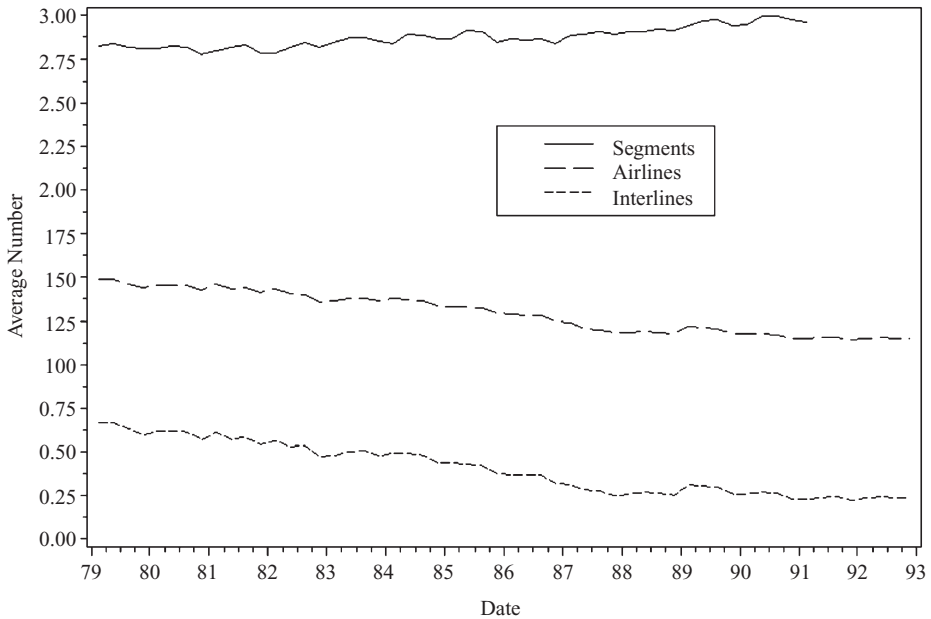


Figure 3. Patterns of Round Trip Itineraries

preferred itineraries on the same airline. This is what would be expected under hub-and-spoke systems.

In summary, the itinerary data suggest that there has been some improvement in the quality of service over the study period. If ignored in the computation of price indices these service quality improvements would artificially inflate the rate of growth in prices.

4.2. *Flight Convenience and Availability*

Passengers typically have clear preferences regarding the time of travel and location of departure. They may choose the expected time of departure or the time of arrival at the final or intermediate destination. The willingness to accept other flight times or locations varies a great deal with trip purpose. Ideally, we would measure when and where the passenger wanted to leave and when and where the passenger left. This is not possible. Instead we proxy this aspect of flight convenience and availability with a hedonic characteristic of service quality measured as the number of departures at the airport of origin. We use the total scheduled departures from DOT's Airport Activity Statistics Form 41 Schedule T3 to measure departures. The more departures that occur (higher flight frequency), the more likely that the time of departure will match the most desired time for the passenger, indicating a higher level of service.

The number of flights at different sized airports has changed since deregulation when airlines were allowed to offer service at some airports and eliminate service to other airports, typically those serving small communities. The pattern of

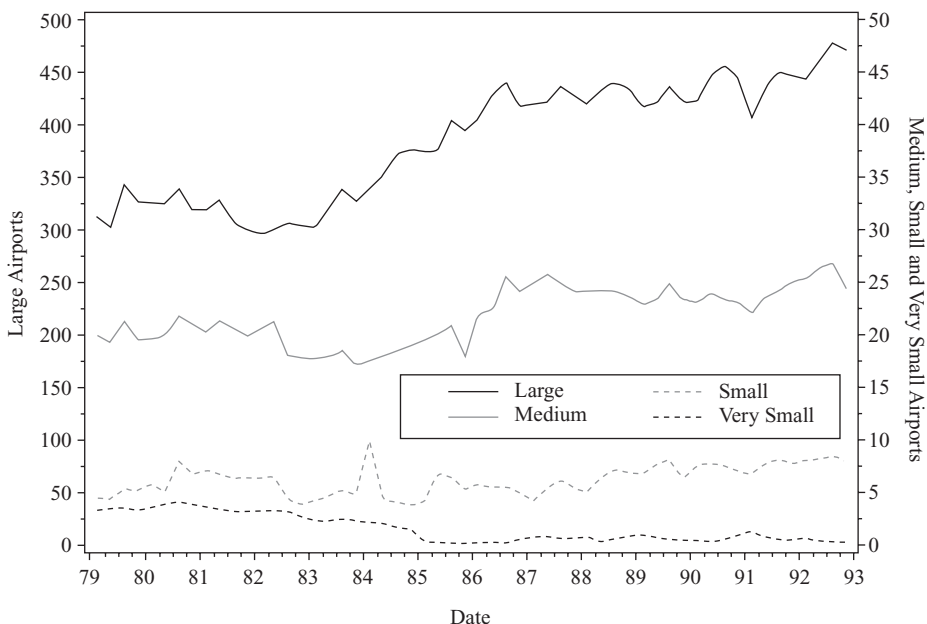


Figure 4. Number of Departures by Airport Size

change in departures for different sizes of airports is displayed in Figure 4. The group of large airports is represented by the 20 airports with the highest total departures between 1979 and 1992. The medium airports are represented by the 20 airports ranked between 100 and 119 in terms of total departures. Small airports are represented by those ranked between 300 and 319, and very small airports are represented by the 20 airports ranked between 400 and 419. Departures increased by 34 percent over the study period for large airports, and by 20 percent for medium and small airports, while departures decreased by 80 percent for very small airports. There was a clear shift from very small to larger cities. From the airline’s perspective the shift was economical since offering service to very small airports that service small municipalities was an expensive proposition when few enplanements could be expected. However, from the passenger’s perspective, offering service to small communities was desirable since it reduced travel time to an alternative city’s airport. For our study, we view departures from small communities as an indication of 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.

Another aspect of higher flight frequency, however, is higher congestion and an increased likelihood of flight delay. This suggests that at some point, higher flight frequency has negative consequences on passenger convenience. Since more tickets are likely to be generated at airports that have high flight frequencies, the impact of the congestion and flight delay consequences of flight frequency is likely to be more apparent in our sample than aspects that represent convenience.

4.3. *Passenger Amenity*

We use hedonic characteristics to measure two dimensions of passenger amenity: food, and class of service. First class service brings with it an array of amenities, among them more space, priority boarding, more attentive service, and a better meal. Class of service is information directly provided for each itinerary in DB1A and thus we know when a particular segment of the itinerary is first class or business class. We construct a dummy variable for this class of service (FirstCl). For carriers that offer only one class of service, typically new entrants, all tickets are reported as first class, even though the characteristics of service more closely resemble coach. Consequently, we have constructed the dummy variable (FCNew) to indicate first class service on carriers which only designate one class of service for their itineraries during the quarter. It is difficult to differentiate this service with a coach ticket designation.

When no-frills airlines began offering service, one of the amenities they most visibly compromised was airline food. It seems clear that the more an airline spends on food the higher will be the quality of service received by consumers and the more they would be willing to pay for service. We obtain information on a carrier's food expenditures from Form 41 Schedule P6 and standardize it by the number of enplanements during that quarter. We then construct an itinerary specific measure by adding the food cost per enplanement for each airline providing service for each segment in the itinerary to measure this service quality characteristic (Food). We also experimented with using the airline's expenditures per passenger mile for proxying food service. This yielded very similar results. In either case, our use of food expense on the itinerary proxies several amenities that are also correlates of food expense in our model. An airline's willingness to spend money on food often indicates a willingness to provide many more amenities.

Figure 5 indicates there has been a gradual increase in food expenditures per passenger. Even when one controls for inflation in food prices, we find real expenditures per passenger increased by about 25 percent during the sample period. If food expenditures were simply passed through, it would indicate that about 3 percent of the price of travel, on average, could be attributed to food expense. This figure masks the large variability in food expenses across airlines. Some carriers, for example Pan Am, spent nearly 20 dollars per passenger on average prior to their merger with National. Low cost carriers like Southwest Airlines spend almost nothing on passenger food.

4.4. *Ticket Restrictions*

A major feature of airline fare structures is ticket restrictions. These may shift the risk of nontravel from airlines to consumers (non-refundability), provide the airlines with improved predictability about demand (advanced booking), or enhance the airline's ability to use price discrimination information separating price sensitive consumers from business travelers with more inelastic demands (Saturday night stay-overs). A major liability of our use of DOT's DB1A as the primary source of ticket information is that it includes very limited information on ticket restrictions. What can be consistently identified from the fare class codes is that some kind of restriction was used on a particular ticket leading to the ticket

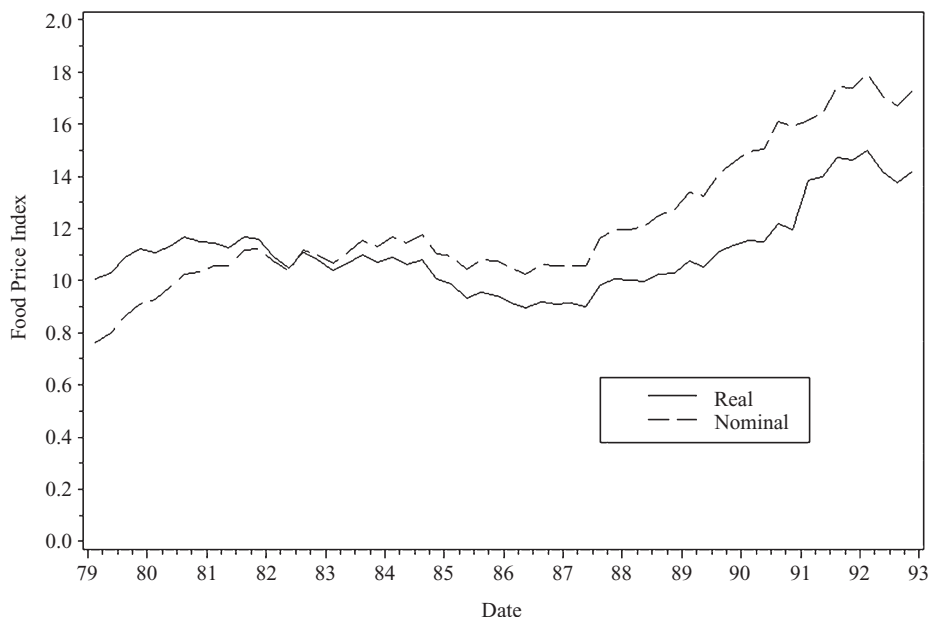


Figure 5. Airline Food Expenditures

being discounted. However, we are unable to identify what the restriction is. Figure 6 shows the fraction of all tickets which were discounted coach tickets for one way and round trip travel during the sample period. The data show a steady increase in both one way and round trip tickets that are discounted coach. For round trip tickets, only 30 percent of tickets were discounted coach in 1979I, increasing to nearly 90 percent by 1992IV.

Yield management practices on the part of airlines add further complications to the discounting process. While two airlines may offer service with an identical fare, their fare structure may be very different because they offer different numbers of seats at that fare. Consequently, it would be inappropriate to model the situation as though the fare described the price at the margin of an individual's willingness to accept the particular restriction. Because of the unavailability of different fares, consumers typically will meet the requirements for 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, with a Saturday night stay fare.

4.5. Frequent Flier Programs and Zero Coupon Tickets

Frequent flyer miles were introduced in the mid 1980s by then CEO Robert Crandall of American Airlines. The purpose behind this program was to increase customer loyalty by offering them free travel at a later date. The program has proliferated to other industries. Grocery stores now offer discounts for frequent

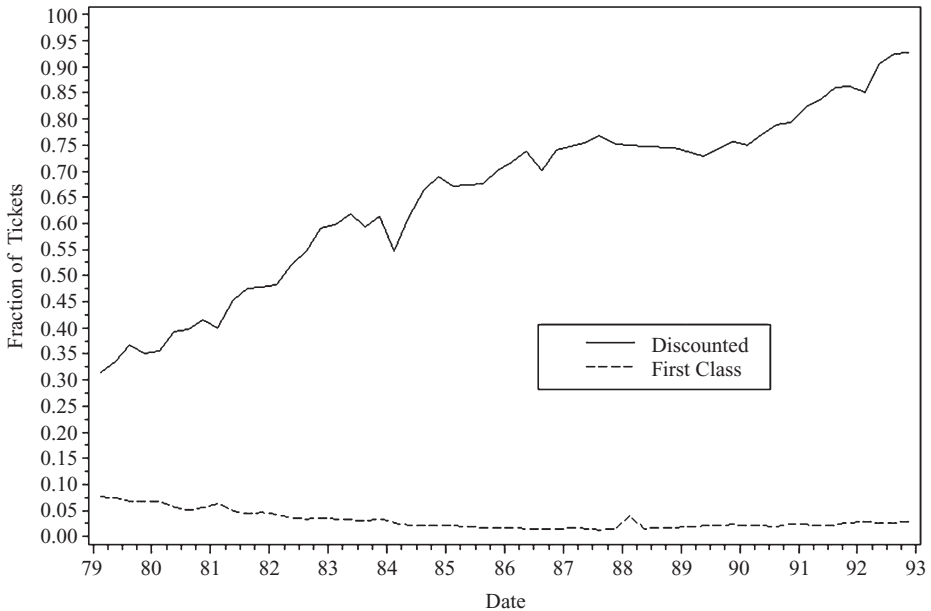


Figure 6. Fraction of Discounted Coach and First Class Tickets

shoppers. The CPI currently ignores zero coupon tickets. The pattern of these tickets from 1979 to 1992 can be seen in Figure 7 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 for both one way and round trip travel. By 1988, these decline to about 5 percent of round trip travel and about 4 percent of one way trips.

The use of zero coupon tickets by consumers is determined by a mix of expectations about their value and the rules that a carrier has for their redemption. During periods of increasing prices we see an increased use of free tickets. An implication of consumers choosing when and where to use zero coupon tickets is 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.

During the period of our study, zero coupon tickets were generated solely by air travel, indicating that they should be used to adjust the effective price of air travel. This view is seriously blurred when, for example, credit card and long distance phone companies began offering frequent flyer miles as part of the inducement to use their services. This raises the issue about where they should be included in the CPI: as adjustments to air travel or the services that generated the frequent flier miles. While conceptually it makes sense to adjust the price of the service that generated the benefit, this is certainly beyond the scope of this paper. It would require that we partition benefits earned by travel from benefits earned by other means and to constantly revise the value of those benefits based on expectations about future air travel prices, the usefulness of the miles based on an airline's

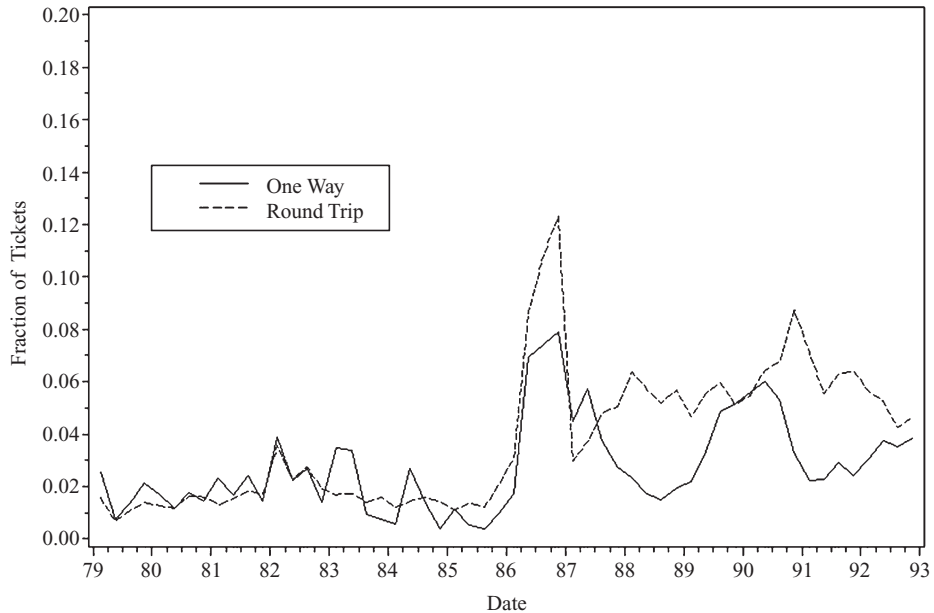


Figure 7. Fraction of One Way and Round Trip Zero Coupon Tickets

network or partnership arrangements, and anticipations about the airline's redemption policy. Instead we adopt an alternative approach that allocates all of the benefits of frequent flier programs to reductions in the price of air travel. We impute the value of zero coupon tickets by our hedonic equation and then construct an expenditure adjustment factor:

$$\lambda = \frac{\text{value of tickets purchased}}{\text{value of tickets used}}$$

The result of this adjustment factor is to lower the effective price index in quarters where a large number of zero coupon tickets were used rather than the quarter where the ticket is earned.⁴

⁴We recognize that our approach is not perfect with respect to zero coupon tickets for at least three reasons. First, there are zero coupon tickets which are systematically excluded from our analysis. Because we use DBIA as our source of information, we do not have consistent information about foreign travel (DBIA includes only those trips which incorporate a trip segment within the U.S.). Consequently, because of data limitations, we suspect that the most expensive zero coupon tickets, those associated with international travel, are systematically left out of the analysis. As a result, our analysis systematically overestimates the price of domestic travel where many of those flights are earned. Of lesser importance, passenger upgrades offered as part of a frequent flier program may also systematically be left out of our analysis if they are not explicitly recorded (passengers get a higher quality of service than we have recorded on their itinerary), again leading to an overstatement of price. Third, those domestic zero coupon tickets that we do include in our analysis almost always come with restrictions including blackout dates, which tend to make them less valuable than the average trip between those city pairs, leading to an overstatement of price. To the extent that these factors are important, data limitations suggest that we will not fully capture the effects of frequent flier programs in our adjusted price index.

4.6. *Route Specific Factors*

Several route characteristics clearly affect the price of travel. Not the least of these is the distance between the origin and destination. Other variables which many have attempted to incorporate into modeling the demand side of long distance travel include weather related variables 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 our model we assume 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). We capture these slowly moving factors with fixed route specific effects which describe the origin–destination pair. In our model this amounts to approximately 115,000 route effects for the one way models and 134,000 for the round trip models.

4.7. *Other Factors*

We also considered the use of other factors. These included safety, circuitry of travel, complaint data, and controls for local demand characteristics such as growth of local GDP and employment rates at origin and destination. Safety was excluded primarily because there is very little data on safety. Aside from the extremely rare event of an actual crash, there is no database that tracks mechanical failures, expenditures on security, etc. Even if changes in security could be tracked, the likelihood is that the security procedures were mandated by unmeasurable increases in security risks. Circuitry of travel, defined as the ratio of actual miles flown to the minimum flight length of the route, was included in some models, but did not perform as well as the number of flight segments. Complaint data was not used because the data are driven by expectations. Persons who expect poor service rarely find it worthwhile to complain when they get it. Local demand factors were excluded for several reasons. With over 115,000 route pairs, collecting local economic data is daunting. Additionally, there is no theoretical reason for regional economic factors to enter into consumer demand equations such as the hedonic index. Combining these facts with significant uncertainty as to usefulness led us to exclude local demand factors from our model.

5. RESULTS

Our intended question is how alternative methodologies to those the BLS currently utilizes affect the Air Fare Index. This requires that we simulate their current methodology over the study period, without the advantage of using their data. We then compare these results to price indices which allow for increased substitutability in market baskets by using sales information and adjust the price index by holding attributes of service quality fixed. These different indices are summarized in Table 1.

The replicated airfare indices for arithmetic and geometric means and the airfare index calculated by the BLS are presented in Figure 8. The replicated indices match fairly well with the actual index reported by the BLS. What differ-

TABLE 1
A COMPARISON OF DIFFERENT INDICES

	BLS Airfare Index	DB1A Arithmetic Mean	DB1A Geometric Mean	Bench Mark Hedonic Model	Hedonic Index w/o Restrictions	Hedonic Index w/o Restrictions
Data Source	SABRE	DB1A	DB1A	DB1A	DB1A	DB1A
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. U.S.	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 Coup Adj.	No	No	No	Yes	Yes	Yes
Inf. w/o Zero Adj	—	—	—	4.82%	5.11%	6.71%
Avg. Inf.	9.80%	10.19%	8.84%	4.42%	4.69%	6.27%

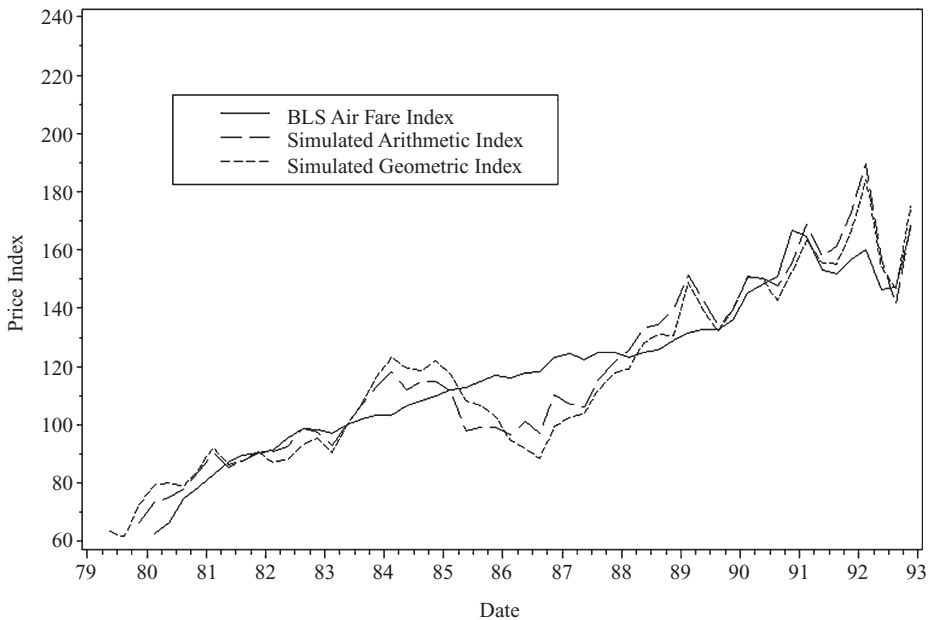


Figure 8. BLS and Simulated Air Fare Indexes

ences 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 is 10.19 percent). The replicated geometric mean series, also with weights that are not entirely fixed, has a lower rate of inflation (average annual inflation is 8.84 percent). This supports the general notion that geometric means lead to lower estimates of inflation.

As we noted in the last section we consider one way and round trip tickets to have key differences in terms of both the passenger and the airline. Consequently, we also develop separate demand models for one way and round trips and discuss these results before combining them in an overall air travel demand model. We first estimate a base model that does not include any aspects of service quality:

$$\ln P_{ijt} = \alpha_j + \beta_t D_t + \varepsilon_{ijt}$$

for ticket i on route j at time t . β_t is the coefficient on a dummy time variable where the reference category is time period 1979I. Omitted service quality characteristics may be correlated with fixed time and/or route effects and thus the ordinary least squares estimates of the α_j 's and the β_t 's may be biased and inconsistent. The predicted price ratio from 1979I to time t is:

$$\frac{P_{jt}}{P_{j,1979I}} = \frac{\exp(\alpha_j + \beta_t)}{\exp(\alpha_j + 0)} = \exp(\beta_t).$$

The estimates for the one way and round trip models are provided in Table 2. Summary statistics including the number of observations, N , and the number of route city pairs, N_j , are also listed. The relatively high R^2 values given such disaggregated data reveal the substantial explanatory power associated with these fixed route characteristics.

The results of this basic model are useful. While they do not adjust for the characteristics of service they do provide a comparison between our 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 our analysis shows that these proportions change substantially over time.

Our hedonic model includes the effects of restrictions and service quality

$$\ln P_{ijt} = \alpha_i + \beta_t D_t + \sum_k \gamma_k X_{kijt} + \varepsilon_{ijt}$$

where the X_{kijt} are the k measures of service quality and ticket discounting for ticket i on route j . In this model we control for the expenditures on food, the number of departures, 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), the class of service (dummy indicating first class) and whether or not the ticket had fare restrictions. Food, interlining and departures are incorporated in logged form. Parameter estimates for the hedonic model without incorporating restrictions model are presented in Table 3 while those for the hedonic model with restrictions incorporated as additional explanatory variables are presented in Table 4.

The signs and magnitudes for the coefficients on food and first class service are as expected. Also, restrictions and discounting lower the price of the ticket. The coefficients on other aspects of service quality remain substantively similar across models. Restrictions mostly affect the price of round trip tickets (where Saturday

TABLE 2
BASE MODEL REGRESSION RESULTS (EXCLUDES QUALITY MEASURES)

Coeff	One Way Model		Round Trip Model		Coeff	One Way Model		Round Trip Model	
	Estimate	Std Error	Estimate	Std Error		Estimate	Std Error	Estimate	Std Error
1979-1	0.00000	0.00000	0.00000	0.00000	1987-1	0.531658	0.000669	0.336607	0.000587
1979-2	0.131647	0.000717	0.084386	0.000627	1987-2	0.557406	0.000660	0.327748	0.000576
1979-3	0.183385	0.000703	0.120222	0.000634	1987-3	0.642275	0.000653	0.397713	0.000582
1979-4	0.271259	0.000688	0.238698	0.000630	1987-4	0.702656	0.000667	0.455133	0.000584
1980-1	0.341144	0.000699	0.326022	0.000638	1988-1	0.750258	0.001217	0.655742	0.001002
1980-2	0.368445	0.000677	0.330174	0.000636	1988-2	0.684097	0.000659	0.502266	0.000571
1980-3	0.347191	0.000677	0.303250	0.000648	1988-3	0.776370	0.001141	0.686379	0.001008
1980-4	0.323089	0.000712	0.318564	0.000639	1988-4	0.686545	0.000669	0.516745	0.000574
1981-1	0.406969	0.000703	0.473544	0.000666	1989-1	0.875029	0.001078	0.907902	0.000929
1981-2	0.391012	0.000679	0.421443	0.000647	1989-2	0.666478	0.000658	0.567267	0.000573
1981-3	0.366208	0.000673	0.423067	0.000669	1989-3	0.566361	0.000648	0.494588	0.000570
1981-4	0.341781	0.000683	0.418745	0.000644	1989-4	0.596645	0.000661	0.510470	0.000562
1982-1	0.341514	0.000682	0.387478	0.000651	1990-1	0.647923	0.000664	0.600511	0.000567
1982-2	0.361650	0.000667	0.409308	0.000636	1990-2	0.676124	0.000655	0.598749	0.000561
1982-3	0.389378	0.000659	0.454254	0.000640	1990-3	0.651849	0.000654	0.540321	0.000563
1982-4	0.376822	0.000682	0.409182	0.000632	1990-4	0.700685	0.000672	0.581347	0.000569
1983-1	0.373201	0.000679	0.345801	0.000629	1991-1	0.619265	0.000674	0.654331	0.000577
1983-2	0.438298	0.000657	0.440545	0.000624	1991-2	0.611315	0.000662	0.570308	0.000563
1983-3	0.450713	0.000649	0.509589	0.000643	1991-3	0.660826	0.000655	0.585231	0.000570
1983-4	0.448037	0.000655	0.530297	0.000628	1991-4	0.670174	0.000669	0.636296	0.000570
1984-1	0.480502	0.000659	0.557338	0.000630	1992-1	0.687399	0.000668	0.757830	0.000582
1984-2	0.491375	0.000645	0.530916	0.000608	1992-2	0.646160	0.000658	0.543558	0.000565
1984-3	0.473786	0.000640	0.510774	0.000618	1992-3	0.641092	0.000652	0.427392	0.000559
1984-4	0.498520	0.000646	0.501107	0.000608	1992-4	0.671827	0.000661	0.634672	0.000572
1985-1	0.500758	0.000651	0.487270	0.000608					
1985-2	0.508989	0.000638	0.413476	0.000595	R2		0.68112		0.44185
1985-3	0.505568	0.000636	0.438910	0.000604	F		113.511		120.919
1985-4	0.423235	0.000635	0.423652	0.000601	N		64,024.141		95,279.537
1986-1	0.429316	0.000637	0.365051	0.000593	Nj		79.248		79,139
1986-2	0.386636	0.000641	0.326974	0.000594					
1986-3	0.454321	0.000628	0.332452	0.000605					
1986-4	0.493267	0.000653	0.386131	0.000597					

TABLE 3
HEDONIC REGRESSION RESULTS WITHOUT RESTRICTIONS

Coeff	One Way Model		Round Trip Model		Coeff	One Way Model		Round Trip Model	
	Estimate	Std Error	Estimate	Std Error		Estimate	Std Error	Estimate	Std Error
In Food	0.057350	0.000062	0.070076	0.000122	1986-1	0.445976	0.000632	0.401204	0.000579
In Dep	-0.077457	0.000210	-0.021254	0.000186	1986-2	0.413581	0.000636	0.366409	0.000580
In Inter	0.319661	0.000547	0.314721	0.000194	1986-3	0.477949	0.000624	0.373821	0.000591
First CI	0.009840	0.000249	0.622013	0.000346	1986-4	0.519626	0.000648	0.430882	0.000582
2 Segs	0.004774	0.000221			1987-1	0.553903	0.000664	0.383329	0.000573
3 Segs			0.000617	0.000217	1987-2	0.582817	0.000656	0.383257	0.000564
4 Segs			-0.109097	0.000208	1987-3	0.662000	0.000649	0.447529	0.000571
1979-1	0.000000	0.000000	0.000000	0.000000	1987-4	0.724473	0.000662	0.503507	0.000573
1979-2	0.119343	0.000708	0.072007	0.000607	1988-1	0.740659	0.001205	0.681558	0.000975
1979-3	0.177663	0.000695	0.111818	0.000614	1988-2	0.721165	0.000654	0.549343	0.000561
1979-4	0.267474	0.000680	0.230940	0.000610	1988-3	0.768125	0.001130	0.707544	0.000982
1980-1	0.333729	0.000691	0.317276	0.000619	1988-4	0.729768	0.000665	0.562544	0.000566
1980-2	0.355464	0.000670	0.321492	0.000617	1989-1	0.862361	0.001068	0.908509	0.000906
1980-3	0.332617	0.000670	0.298420	0.000629	1989-2	0.701687	0.000653	0.604131	0.000565
1980-4	0.288215	0.000705	0.311909	0.000621	1989-3	0.606047	0.000644	0.536835	0.000562
1981-1	0.375977	0.000695	0.457073	0.000647	1989-4	0.634399	0.000656	0.545739	0.000555
1981-2	0.365019	0.000672	0.423952	0.000628	1990-1	0.678261	0.000662	0.629540	0.000562
1981-3	0.330924	0.000667	0.420699	0.000651	1990-2	0.715318	0.000655	0.631447	0.000558
1981-4	0.305416	0.000677	0.413868	0.000627	1990-3	0.685130	0.000654	0.570096	0.000562
1982-1	0.309437	0.000675	0.382742	0.000633	1990-4	0.738359	0.000672	0.611860	0.000566
1982-2	0.336192	0.000661	0.422916	0.000618	1991-1	0.651171	0.000673	0.682229	0.000574
1982-3	0.361963	0.000653	0.462897	0.000623	1991-2	0.643303	0.000663	0.603464	0.000562
1982-4	0.351123	0.000675	0.426553	0.000615	1991-3	0.696390	0.000657	0.615449	0.000571
1983-1	0.348629	0.000673	0.363538	0.000612	1991-4	0.714363	0.000670	0.666161	0.000569
1983-2	0.411501	0.000651	0.462283	0.000607	1992-1	0.732743	0.000670	0.778981	0.000582
1983-3	0.426179	0.000643	0.531412	0.000625	1992-2	0.692213	0.000660	0.573328	0.000565
1983-4	0.417013	0.000649	0.546810	0.000611	1992-3	0.695754	0.000656	0.462976	0.000559
1984-1	0.453261	0.000654	0.569750	0.000613	1992-4	0.722949	0.000664	0.667230	0.000571
1984-2	0.466200	0.000640	0.549884	0.000593					
1984-3	0.448623	0.000635	0.531523	0.000602	R2		0.68254		0.48334
1984-4	0.480478	0.000640	0.525912	0.000592	F		133,347		222,150
1985-1	0.482905	0.000645	0.511242	0.000592	N		64,024,141		95,279,542
1985-2	0.494214	0.000633	0.446156	0.000579	Nj		79,248		79,139
1985-3	0.523423	0.000631	0.471529	0.000589					
1985-4	0.442321	0.000629	0.460142	0.000586					

TABLE 4
HEDONIC REGRESSION RESULTS WITH RESTRICTIONS

Coeff	One Way Model		Round Trip Model		Coeff	One Way Model		Round Trip Model	
	Estimate	Std Error	Estimate	Std Error		Estimate	Std Error	Estimate	Std Error
In Food	0.035667	0.000064	0.073075	0.000119	1986-1	0.550154	0.000623	0.562686	0.000569
In Dep	-0.069821	0.000205	-0.025848	0.000181	1986-2	0.523665	0.000628	0.536447	0.000571
In Inter	0.311014	0.000536	0.282482	0.000190	1986-3	0.578357	0.000616	0.540619	0.000581
First CI	0.450880	0.000510	0.511057	0.000467	1986-4	0.621167	0.000639	0.602813	0.000573
FCNew	-0.746571	0.000601	-0.079969	0.000920	1987-1	0.656667	0.000654	0.545567	0.000564
F Restrt	-0.163372	0.000917	-0.336050	0.000863	1987-2	0.685043	0.000647	0.550922	0.000555
Y Restrt	-0.143883	0.000135	-0.294731	0.000134	1987-3	0.769153	0.000640	0.619987	0.000562
2 Segs	0.004774	0.000221	-0.002569	0.000211	1987-4	0.821586	0.000652	0.675525	0.000564
3 Segs			-0.108666	0.000202	1988-1	0.763661	0.001179	0.671467	0.000950
4 Segs			0.000000	0.000000	1988-2	0.810117	0.000644	0.722428	0.000950
1979-1	0.000000	0.000000	0.000000	0.000000	1988-3	0.798768	0.001106	0.697766	0.000957
1979-2	0.130343	0.000693	0.083149	0.000592	1988-4	0.809356	0.000654	0.736161	0.000957
1979-3	0.194426	0.000665	0.127450	0.000598	1989-1	0.876850	0.001046	0.878056	0.000883
1979-4	0.276723	0.000676	0.240001	0.000595	1989-2	0.783943	0.000653	0.766493	0.000553
1980-1	0.344044	0.000656	0.310714	0.000603	1989-3	0.684838	0.000643	0.709309	0.000553
1980-2	0.383116	0.000656	0.324051	0.000601	1989-4	0.711496	0.000645	0.720662	0.000547
1980-3	0.360788	0.000656	0.311709	0.000613	1990-1	0.862975	0.000657	0.800734	0.000554
1980-4	0.321839	0.000690	0.351941	0.000605	1990-2	0.901681	0.000651	0.807870	0.000551
1981-1	0.406595	0.000681	0.493380	0.000631	1990-3	0.877281	0.000651	0.749520	0.000554
1981-2	0.403843	0.000659	0.474508	0.000612	1990-4	0.930724	0.000668	0.888713	0.000559
1981-3	0.377461	0.000654	0.475235	0.000635	1991-1	0.850231	0.000670	0.863407	0.000566
1981-4	0.351862	0.000664	0.471488	0.000611	1991-2	0.844376	0.000659	0.798129	0.000555
1982-1	0.390685	0.000662	0.441142	0.000618	1991-3	0.901937	0.000654	0.813627	0.000564
1982-2	0.390338	0.000648	0.492552	0.000603	1991-4	0.922502	0.000668	0.858237	0.000563
1982-3	0.416864	0.000640	0.540316	0.000608	1992-1	0.943008	0.000667	0.962937	0.000575
1982-4	0.406532	0.000662	0.526693	0.000601	1992-2	0.906864	0.000659	0.775220	0.000560
1983-1	0.404044	0.000660	0.463098	0.000598	1992-3	0.910479	0.000654	0.667321	0.000594
1983-2	0.472538	0.000638	0.563095	0.000593	1992-4	0.941617	0.000663	0.869538	0.000565
1983-3	0.488926	0.000631	0.623636	0.000611	R ²		0.70285		0.49699
1983-4	0.483680	0.000637	0.657317	0.000598	F		177.380		301.484
1984-1	0.516296	0.000641	0.667603	0.000599	N		64.024141		95.279542
1984-2	0.568221	0.000630	0.677280	0.000581	N _j		79.248		79.139
1984-3	0.557910	0.000625	0.679142	0.000591					
1984-4	0.588324	0.000631	0.680385	0.000581					
1985-1	0.585641	0.000635	0.658956	0.000581					
1985-2	0.597059	0.000623	0.596044	0.000568					
1985-3	0.620830	0.000622	0.621574	0.000578					
1985-4	0.551832	0.000622	0.611416	0.000576					

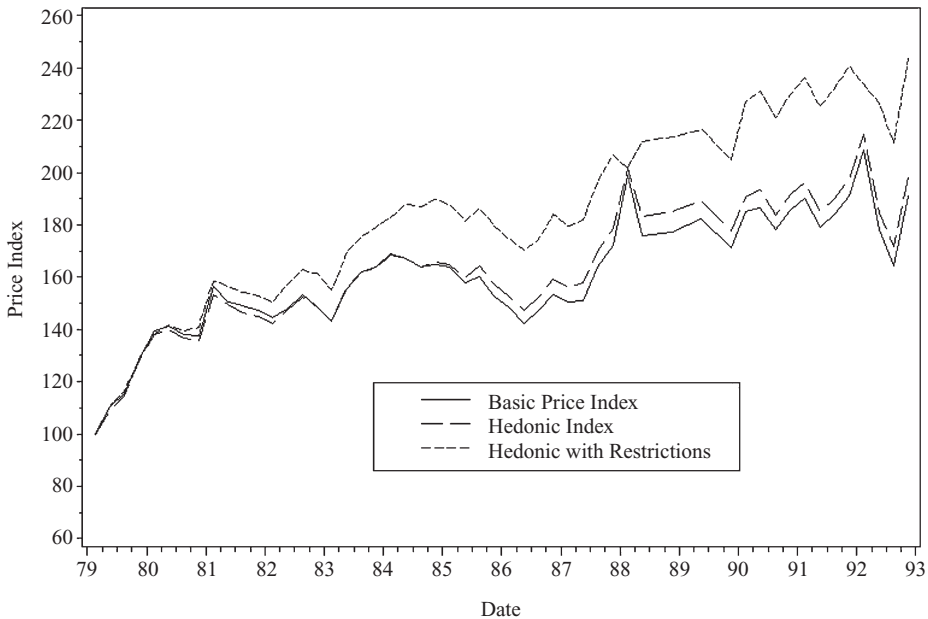


Figure 9. Hedonic and Base Model Regression Indexes

night stayovers can be enforced) and have relatively little effect on one way trips: lowering the price of one way trips by approximately 15 percent and the price of round trip tickets by approximately 30 percent. These reductions hold regardless of class of the ticket (first class or coach).

To generate price indices for the base and hedonic models, it is necessary to aggregate the one way and round trip price indices. This is accomplished by taking their expenditure weighted geometric mean value:

$$\frac{P_t}{P_{t-1}} = \left(\frac{\beta_t^1}{\beta_{t-1}^1} \right)^{k_t^1} \left(\frac{\beta_t^2}{\beta_{t-1}^2} \right)^{k_t^2}$$

where β_t^1 and β_t^2 are coefficients based on one way and the round trip tickets, respectively; and k_t^1 and k_t^2 are the expenditure shares of one way and round trip tickets, respectively.⁵ We have constructed these indices for the base model and the hedonic model. The results are presented in Figure 9.

Finally, we turn to adjusting the indices based on the base model and our hedonic model for zero coupon tickets. Since we have imputed values associated with all zero coupon tickets, we can use this to obtain the effective price as a deflator. The indices generated by our base and hedonic regression models are

⁵The formula we use is a geometric mean, but only of two components, one way and round trip, and not of each individual route as with Lent and Dorfman. Also, our weights are different for each time period. This index number is referred to as the Young index. All variants of the Young index pass the standard requirements, except that when there are exceptional relative price or quantity changes, monotonicity breaks down. This is not the case for our data (Balk, 2008).

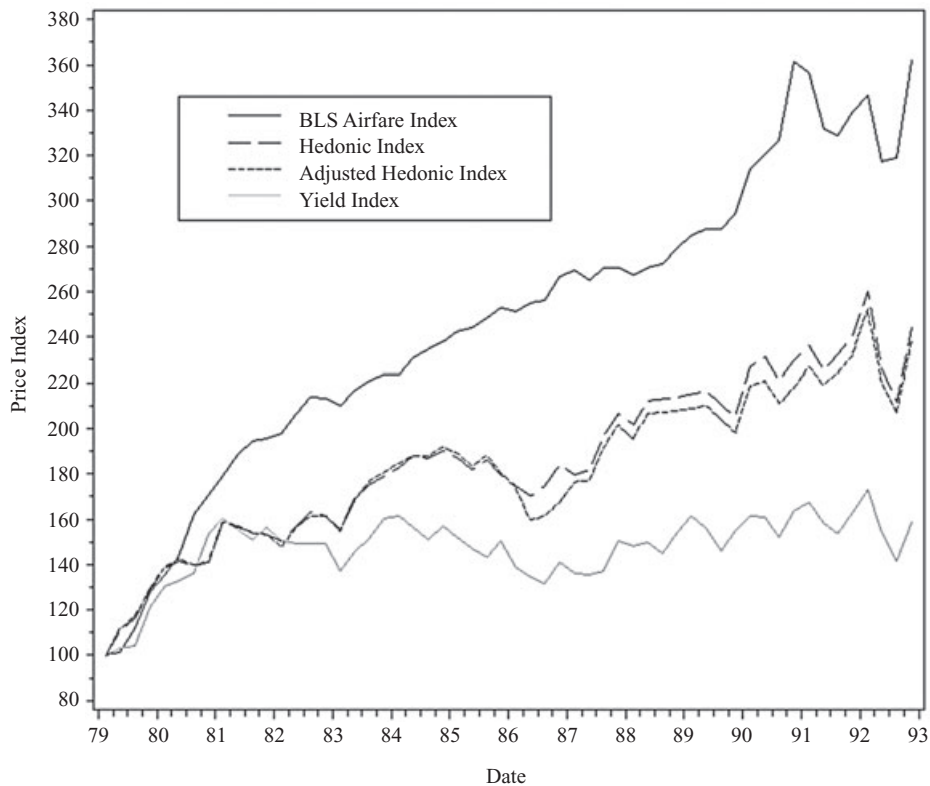


Figure 10. Zero-Coupon Adjusted Hedonic Index Compared to other Indexes

presented in Figure 10. As an additional reference, we include an index for the unadjusted revenue yield (revenue per passenger mile flown, normalized to be 100 in 1979I). Notice that the yield index (growing 3.65 percent per year over our study period), which incorporates no quality adjustment, grows at a much lower rate after airline deregulation in the U.S. gave carriers authority to set their own prices and determine their own routes in 1980. Airlines initially used this authority to rationalize their route structures, eventually leading to a use of hub-and-spoke type networks and an indirect routing of some passengers, particularly between less common origins and destinations. Together with an increase in trip length (revenue per mile for long trips is lower than revenue per mile for short trips), this suggests that the yield index substantially underadjusts for changes in price.

Comparing these indices with the hedonic index leads to an interesting conclusion. The hedonic index has an average annual inflation of 6.27 percent. This is much lower than any of the other indices (with the exception of the revenue yield index). 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. 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 our bench mark

regression. The 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 percent, indicating that adjusting for quality increases inflation by a small amount. The appropriate conclusion can only be that quality fell 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 DBIA data set can identify over 134,000 different routes in the sample period. It is unlikely that all substitution biases are dealt with when the consumer can only substitute among 0.5 percent 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 subindices 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.⁶

6. CONCLUSIONS

In our research we have attempted to take an exhaustive approach to measurement issues in price index construction for the BLS airfare index. While our findings are constrained by data availability and other resource constraints that may not be as constraining for government agencies, we have nonetheless been able to pursue a number of the objectives for dealing with the biases that the 1997 CPI Commission recommended be addressed. We have also provided a detailed protocol for data collection and analysis that can be replicated and can be enhanced by availability of additional data sources. We find an upward bias in the BLS airfare index over the period considered. However, we have also found that

⁶Lent and Dorfman (2005) have used the same origination–destination information as we do, though their study interval is between 1995 and 2002. Their approach follows the standard BLS approach based on matching, though they require that like items match on both fare class and the exact itinerary. Compared to the BLS index, their approach leads to the inclusion of a much broader basket of trips. However, a shortcoming in their approach is that nearly half of the itineraries do not have exact matches. They carry out an imputation to adjust for the non-matching items based on trip distance. Though the contrast may appear subtle, our approach relies on the DOT supplied trip-break indicators to identify the destination in round trip travel. Travel between the origin and the destination is, after all, what is ultimately demanded by the passenger. Were we to implement matching over our study period, there would be an even more substantial number of non-matches since deregulation and mergers led to many reconfigurations of the airlines' networks. There were approximately 15 mergers and service cessations among major carriers over our study period, while the industry was much more stable between 1995 and 2002 with only two major service cessations. Indeed, we chose our study period because of its volatility. We explored the use of an alternative circuitry measure (itinerary distance/origination–destination distance) as an additional variable in our hedonic model, but found it to be highly collinear with our measure of indirect routing (number of ticket coupons), and consequently, we left it out of our final model. Of course, our hedonic model allows us to incorporate other attributes for which matching is difficult to implement, and that Lent and Dorfman do not consider, such as passenger interlining.

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, are 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.

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