Terrorism and the Alchian-Allen Theorem

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The Alchian-Allen "effect" occurs when the fixed cost of purchasing a good is altered. Initially fixed costs imposed on consumers of airline flights due to terrorism were low. Coach airfares increased relative to business and first class fares due to security costs. Since air fares are flexible, the ratio of coach fares to business or first class fares should fall. Using quarterly fare data for the period 1995-2005 from DOT's Database 1B, analysis shows a significant effect on relative shares of air travel. The sign of the effect is negative indicating that first class declined relative to coach travel

INTRODUCTION

The Alchian-Allen Theorem (or Alchian-Allen "effect") is the process of changing the relative prices of two goods by changing the magnitude of a fixed cost the consumer must pay regardless of which good is purchased. (Alchian and Allen, 1968) More formally, consider the price ratio $\mathbf{P_A/P_B}$, where $\mathbf{P_A}$ is less than $\mathbf{P_B}$. Furthermore, let **C** equal a fixed cost to be added to both $\mathbf{P_A}$ and $\mathbf{P_B}$. The ratio of full costs is $\boldsymbol{\alpha}$ as in equation 1.

$$\boldsymbol{\alpha} = (\mathbf{P_A} + \mathbf{C})/(\mathbf{P_B} + \mathbf{C}). \quad \textbf{(1)}$$

The value of $\boldsymbol{\alpha}$ will increase as **C** increases. As $\boldsymbol{\alpha}$ increases, the relative difference between the full cost of good A and that of good B decreases. In other words, as the fixed cost increases, the more expensive good becomes more attractive to the consumer. We apply this simple mathematical phenomenon to the consumer choosing between first class and "coach" airline tickets.

Suppose a consumer is pricing round trip tickets from Atlanta to New York City and finds coach tickets priced at $414 each, while first-class tickets are $691. In a pre-September 11, 2001 world, we assume the typical consumer had little concern of terrorism. The tragic events of that day most certainly changed perceptions of the risks involved with flying. Because terrorist activity does not distinguish between coach and first class customers, we treat it as a fixed cost that must be added to the cost of a plane ticket – regardless if coach or first class. The customer's valuation of the cost of terrorism that must

be borne when flying is dependent on his perceived probability of a terrorist event taking place. Indeed, this perception need not be tied to the actual risk. (While consumers' perceptions of the risk of terrorism occu, rring when flying changed considerably in the wake of September 11, the actual risk of terrorism probably did not. In the world of consumer behavior, perception trumps reality.)

Suppose a pre-9/11 consumer estimates the cost of terrorism that he must bear is $50 (round trip). The price ratio of coach to first class is:

α = ($414 + $50)/($691 + $50) = ($464/$741) = 0.626 **(2)**

In the days following 9/11, suppose the perceived cost of terrorism climbed to $250. This changes the price ratio:

α = ($414 + $250)/($691 + $250) = ($664/$941) = 0.706 **(3)**

So after the events of 9/11, the ratio of the (perceived) full cost of flying coach to first class has increased. If the ticket prices of each fare class remain constant, this change makes flying first class more attractive to consumers. Testable hypothesis: the ratio of first class to coach ticket sales increased in the days after 9/11, after adjusting for nominal prices. In order for this hypothesis to be supported empirically, there must be some flexibility in the ratio of first class to coach seats available to consumers. This, in turn, requires flights to have empty seats at the time of take-off. If a plane is filled to capacity, the ratio of first class passengers to coach passengers is merely a function of the layout of the airplane; and we have no way of knowing how many customers were turned away due to availability.

If airlines choose to (in the short run) keep the ratio of first class seats to coach seats fixed, they will have to adjust their ticket prices in order to keep the *full price* ratio of first class to coach tickets constant. Returning to our example, the pre 9/11 full price ratio of 0.626 is assumed to be appropriate given consumer preferences and the ratio of first class to coach seats available in the airplane. After 9/11, the airline will adjust ticket prices in order to maintain this ratio. Note that the ratio of ticket prices when C is 0 is 0.599 ($414/691). We hypothesize that as C rises due to a greater perceived terrorism risk, the ratio of coach to first class ticket prices rises in an effort to keep the ratio of full prices constant.

THE MODEL

In our application of the Alchian-Allen Theorem to the threat of terrorism in commercial flying, we propose the following model:

Sales Ratio = *f*(Itinerary Yield, 9/11 Binomial, number of coupons, number of passengers on a given itinerary, quarterly and annual dummies, route identifiers)

Where, **Sales Ratio** is the number of the number of coach tickets purchased divided by the number of first class tickets purchased on the observed flight; **Itinerary Yield** is the cost to the consumer per mile traveled on the observed itinerary; **9/11 Binomial** is a dichotomous variable equal to 0 if the date of the observed flight is prior to third calendar quarter of 2001, and equal to 1 if the date is after; **Quarterly and annual dummies** compensate for seasonal variation and growth in the number of flights. Route identifiers are dichotomous variable equal to 1 if the observed itinerary departs or arrives in in a particular end point city, equal to 0 otherwise;

We expect the price ratio will be inversely related to the sales ratio, as the law of demand would dictate. This variable is a necessary component of **α** as defined above.

The coefficient of the 9/11 Binomial is expected to be inversely related to the Sales Ratio. After 9/11 (when the value of the binomial is 1) the value of **C** in equation 1 will increase due to fears of terrorism. A higher value of **C** will result in a higher value of **α**, that is, a higher coach to first class price ratio. This higher price ratio will put downward pressure on the coach to first class ticket sales ratio. If the coefficient of 9/11 is indeed negative, it suggests that the Alchian Allen Theorem is responsible.

The risk of terrorism – and hence, value of **C** - will also be higher for flights in and out of cities are of high value to terrorists. We assume New York City and Washington D.C. to be target cities and therefore

expect the Sales Ratio to be lower for flights to and from them. The coefficient of Target Cities Binomial is expected to be negative.

An additional cost that fliers must bear regardless of whether they purchase coach or first class tickets is the value of their time that must be invested when taking a flight. The total time per flight has a fixed component (checking bags, going through security, etc.) as well as a variable portion which we proxy with the distance flown. We expect first class tickets will be more popular on longer flights for a variety of reasons. We reason that consumers value the added comfort and other amenities that first class seating provides more on longer flights. Additionally, viewing the time cost as a component of **C** in equation 1, will change the relative prices facing consumers in favor of first class travel.

NOTES ON DATA

The primary data for this paper comes from the Database 1B survey of the US Department of Transportation. (United States, Department of Transportation, 1995-2005) This is the product of a survey of 10% of all ticketed airline itineraries, executed quarterly.

Two subfiles of this survey are employed. The primary subfile is the DB1BTicket survey. This provides, origin and destination information, whether the ticket is round trip, on a single carrier, and the number of passengers. In addition, the itinerary yield per mile and per person is provided, along with the itinerary distance.

The other subfile employed is DB1BCoupon. This file reports the fare class of the flight coupons issued for each sampled itinerary. The fare class classification is presented in Appendix 1 below. Because itinerary numbers are provided for each of these databases, the fare class reported here can be matched with the fares reported in the Ticket database. In order to distinguish coach from business and first class fares, the mean and variance of fares paid per person for each fare class is computed.

Each quarter has between six and eight million observed itineraries. The variables were downloaded for each calendar quarter from 96:1 through 05:4. This lead to a total sample of approximately 176 million observations over 40 quarters.

Appendix 1 shows the definitions of the various fare classes. As a general rule, "restricted" tickets are less expensive than their "unrestricted" counterparts. Thus, typically the cheapest tickets available for fliers are *restricted coach class*. Figure 1 shows the relative quantitative shares of the two coach and the two first class classifications. Clearly restricted coach is the most important fare class in terms of the number of passengers. Because the detailed performance of restricted versus unrestricted first class is obscured due to scale effects, Figure 2 shows the quantities of each. Clearly the quantities of each varied substantially over the sample period.

In addition to quantities, the mean quarterly fare for each class was computed. Figure 3 illustrates the performance of the fares applied to coach passengers. Clearly the mean value of unrestricted coach fares was substantially constant over the sample period, while the value of unrestricted coach fares mostly declined. Figure 4 illustrates the same fare comparison for first class passengers. Clearly the itinerary yields for first class fares were more volatile. However, restricted fares appear to have usually been lower than the alternative. In the next section, we consider the statistical procedures which will be adopted to test the Alchian-Allen effect.

FIGURE 1
RELATIVE SHARES OF MAJOR FARE CLASSES

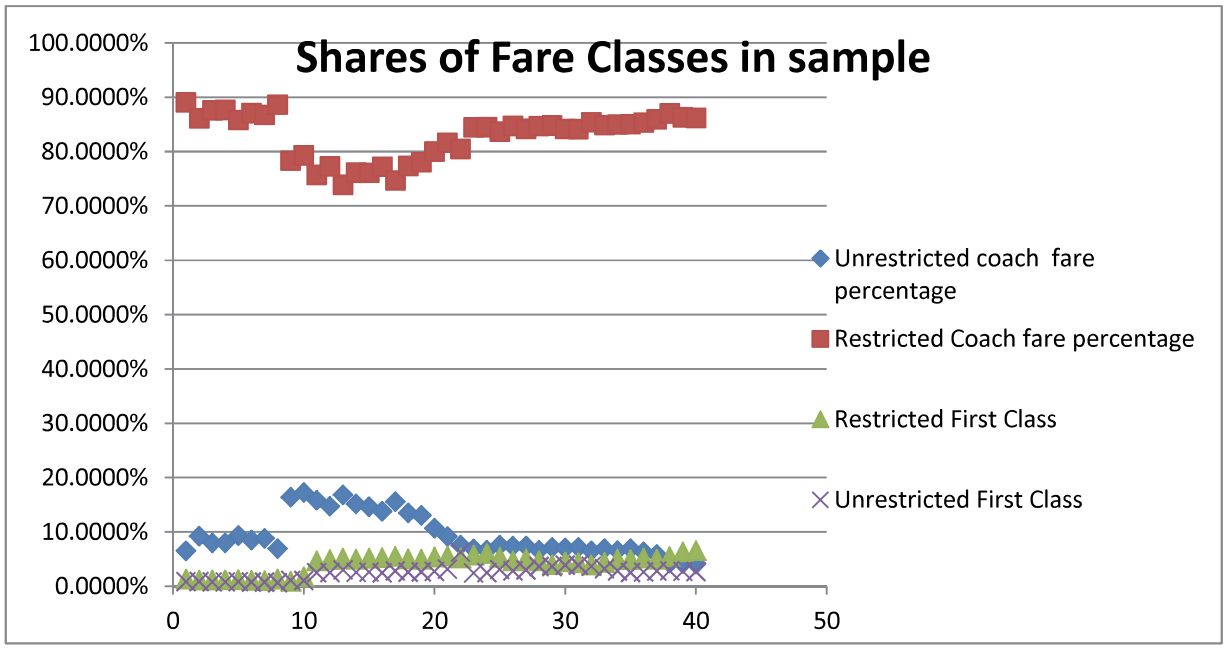


FIGURE 2
FIRST CLASS QUANTITIES 1995:1 - 2005:4

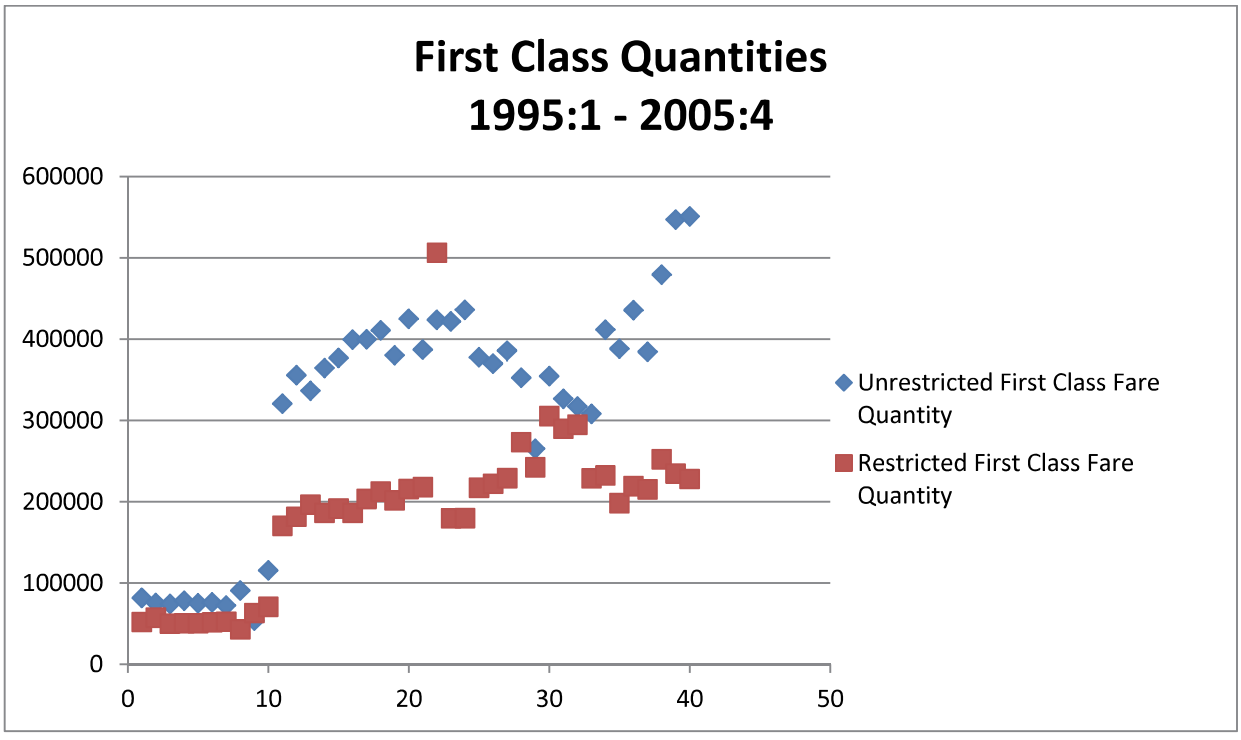


FIGURE 3
ITINERARY YIELDS OF COACH CLASS

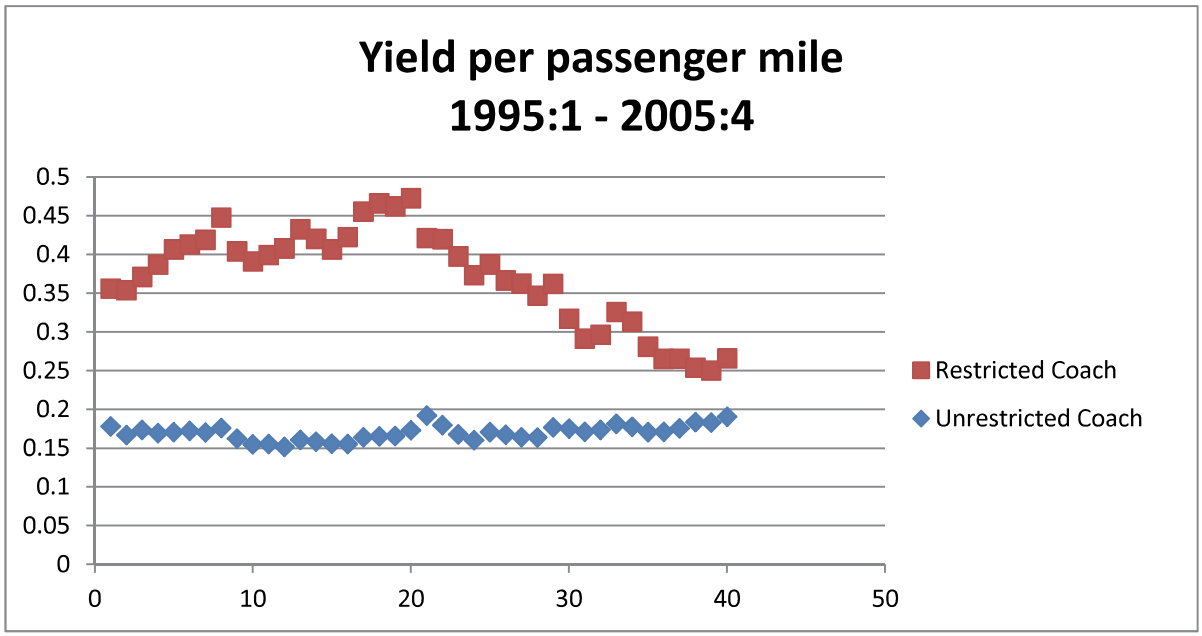
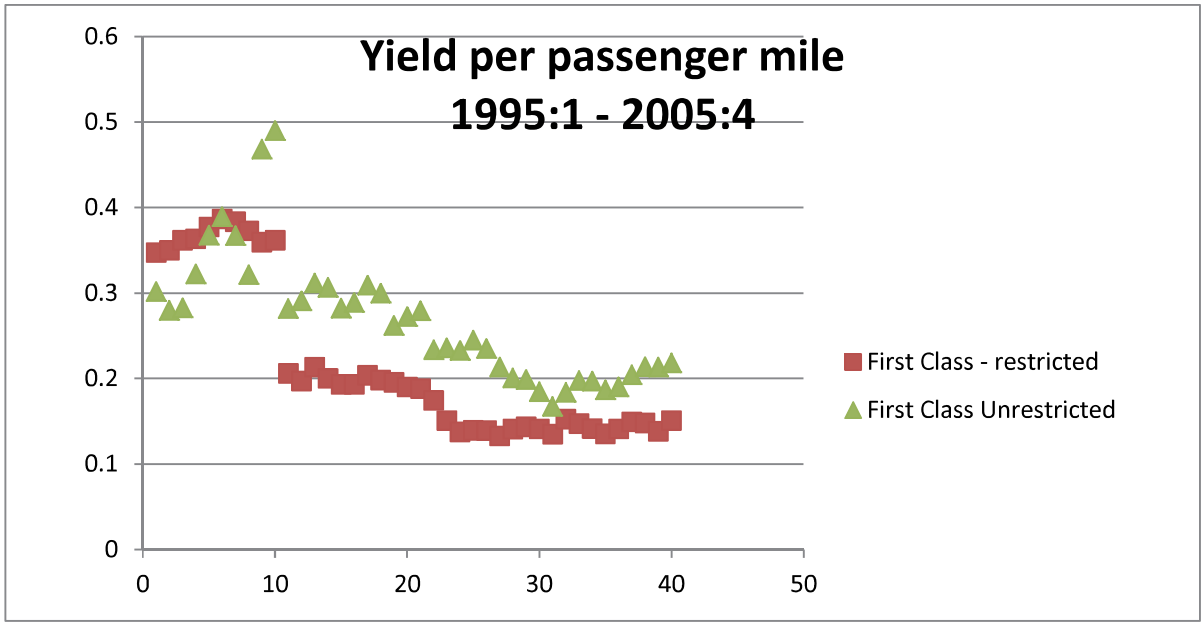


FIGURE 4
ITINERARY YIELDS OF FIRST CLASS



STATISTICAL ESTIMATES TESTING ALCHIAN-ALLEN

Two distinct sets of statistical analyses were run with the data described in the preceding section. The first considered quarterly data from the first quarter of 1996 through the fourth quarter of 2005. The second applies a binomial logit procedure to a sample of largest originating metropolitan areas in the more limited time period of the first quarter of 1999 to the fourth quarter of 2003

The data considered with the total number of itineraries in each fare class and the quarterly average itinerary yield for each fare class. The attached notes for database 1B note that airlines' employment of fare codes is not standardized and recommends against their use for analytical purposes. However, computing the mean and standard deviation of the itinerary yield by fare class shows that the mean values for each fare class are statistically distinct from any other fare class. Summary statistics for these variables are provided in Appendix 2.

Consistent with the discussion above, the dependent variable is the ratio of restricted first class itineraries to the number of restricted coach fares. Unless there are different time series responses for first class and coach, this procedure eliminates serial correlation due to seasonal patterns in airline data. The independent variables are the ratio of restricted first class fares to restricted coach fares and a variable incorporating the effects of the 9/11 event. This variable takes two different forms. The first (Terror911) is a simple dummy assigned the value of 0 for all observations prior to third quarter 2001 and taking the value of 1 for subsequent quarters. The second (yield911) is the result of interacting average itinerary yield with the Terror911 variable, to determine if the 911 event changed the relationship between the independent variable and yields. The *a priori* expectation is that the Terror911 variable will have a positive sign reflecting a common increase in fixed costs to all classes of flyers. On the other, hand yield911, should have a negative sign, indicating a more inelastic response to the differential between first class and coach yields. The results of these regressions appear in Appendix 3.

Both regressions are highly significant with regression analytics indicating essentially no probability that the relationship revealed could have arisen by chance. Both explanatory variables and the constant term are significantly different from zero with little possibility that these coefficients are statistical artifacts. The relationship of relative itinerary yield per mile and relative numbers of first class and coach itineraries is negative in both regressions. This is consistent with *a priori* expectation that when a relative price changes, quantity will change in the opposite direction. It is noteworthy that the slope coefficient is unchanged between the treatment of the 911 indicator as a simple dummy or an interacted term. This is also true of the constant term.

The 911 indicator variables are both negative and statistically highly significant. In the case of Terror911 this is contrary to the expectations of the Alchian-Allen Theorem where an increase in fixed costs (e.g. more intrusive passenger screening or subjective costs associated with risk averse responses to the threat of terrorism) should reduce the costs of first class fares relative to coach fares similarly restricted. The yield911 variable, which represents an adjustment to the itinerary yield and indicates more inelastic demand, has the expected negative sign.

Since one result is counterintuitive, further analysis seems warranted. In the next stage, rather than quarterly summaries, actual itinerary observations are utilized. The model envisioned here is that each observed itinerary represents a single point along a demand curve for one of the fare classes. Airline firms are able to practice nearly perfect price discrimination charging each customer their reservation price. Unfortunately DB1B provides no demographic data on individuals accepting particular itineraries. Thus hedonic estimation of the demand curves must proceed from a limited menu of explanatory variables.

As noted previously, the sample is now restricted to the twenty months immediately adjacent to the 9/11 events. This resulted in a sample of approximately 156 million observations. The resulting database was too large to permit estimation with available computational resources. Using Stata, a random sample of 50% of the observations was constructed. This represents a five percent sample of all national itineraries during the period.

The sample was then restricted to just the itineraries serving the top 50 air travel originating metropolitan areas. This data was developed from the publication: *Domestic Airline Fares Consumer Report: Third quarter 2000 Passenger and Fare Information*. (See Appendix, Market definition glossary)

The independent variables for these binomial logit procedures were, the itinerary yield of each observed itinerary, the number of coupons per itinerary, the number of passengers traveling on an itinerary, the distance of the itinerary, and dummy variables identifying year and calendar quarter of each observation (1998 and fourth quarter omitted during estimation), and dummies representing the market in which the itinerary is located. There are also a variables (Terror911 and Yield911) distinguishing the post-911 observations from the pre-911 observations.

Expectations regarding the likely values of coefficients for this limited pallet of variables are as follows. Itinerary yield ought to be negative, reflecting the law of demand, i.e. a higher price per unit of a product (coach vs first class) will reduce demand for the product whose relative price increased. The number of coupons per itinerary captures how circuitous, and thus, how inconvenient a route is for consumers. This variable ought to have a negative coefficient. The number of passengers traveling on a particular itinerary may also have a negative coefficient, reflecting the additional expense of multiple passengers booking together. The year and quarter dummies are standard procedure for panel data investigations and their coefficients have no particular economic significance. The dummies representing individual markets capture the unique demographic and geographic features of each market but are limited to the top markets. These dummy variables are defined at equal to 1 for any flight with an origin in one metropolitan area and terminating in another, and zero otherwise. For instance, the variable wshnyc takes a value of 1 for any flight from the three DC area airports (National, Dulles, and Baltimore-Washington, to any of the New York metropolitan airports (Newark, LaGuardia, and JFK), and zero otherwise. In keeping with the theory presented above, the Terror911 variable ought to have a positive sign.

The final variable to be considered in the estimates is the itinerary yield. Standard price theory suggests that the coefficient of this should be negative, as it was in the results reported previously. Summary statistics for the variables are provided in Appendix 4.

As noted above, our dependent variable is valued zero for restricted coach class while restricted first class equals one. This is entirely appropriate in terms of our theoretical model which posits a particular change (decreased representation of the "low" priced alternative.

Appendix 5, the first column presents the results of binomial estimates with a simple Terror911 variable. The second column adds dummy variables identifying the routes most likely to be affected by the 911 event. (I.e. those beginning or terminating in Washington, DC or New York City) Annual and quarterly dummy variable coefficients are suppressed. The resulting estimates are statistically significant at levels well beyond conventional levels of significance. The Pseudo R^2 estimates that approximately 2.3% of the variation of the dependent variable is explained by the independent variables employed. This is lower than the usual R^2 results of a panel data estimate. However, this is consistent with the context of these estimates where no data is available regarding the characteristics of individuals selecting a particular itinerary. When the route specific dummy variables are added the regression diagnostics are improved.

Turning to the parameter estimates, all parameter estimates are statistically significant at a more than 95% level which is to be expected given the very large sample size. The coupons variable which functions as a measure of an itinerary's inconvenience has the expected negative sign. The number of passengers on an itinerary has a positive sign. Itinerary yield has the expected negative sign when the when only Terror911 is added. When the route dummies are added (in the second column) the sign reverses.

The dummy indicating that an observation is post-9/11 has a positive and significant sign. This result is consistent with the expectations conditioned upon the Alchian-Allen effect but inconsistent with the prior results based upon quarterly aggregates. This result suggests that there were indeed, a greater proportion of restricted first class passengers after 9/11. One possible explanation for this could be that aircraft flew with passenger loads well short of capacity after 9/11. Thus first class seats were no longer capacity constrained.

Panel 5B has similar parameter estimates after the addition of dummy variables representing the airline routes most subject to a 9/11 effect. The Chi squared measure of goodness of fit is substantially improved as is the pseudo-R^2. Most of the parameter estimates for these variables possess values of less than -1. There are two notable exceptions to this pattern. Eastern "vacation" destinations, i.e. Florida-NYC have parameter estimates that are much smaller in absolute value, and in some cases positive. The two largest metropolitan areas in California, Los Angeles and San Francisco also have smaller parameter values. In addition, the combined West Coast and vacation destination Las Vegas has a positive parameter.

All of the parameter estimates reported are statistically significant at levels well above those conventionally employed. However, as noted below the panel, the package reported that 24000 observations exactly matched the estimated relationship for failure which may be reflected in inaccurate estimates of parameter standard errors. Since these observations represent only 0.00006% of the sample, this concern seems somewhat innocuous.

Appendix 6, panels A and B, show parameter estimates where a dummy generated by interacting the 911 dummy with itinerary yield is substituted for the simple indicator. The general regression measures of goodness of fit are similar in value to the estimates reported above. Most parameter estimates are similar to the estimates of Appendix 5.

However, two parameters are quite different. The first is itinerary yield. This flips from a negative value in the prior estimates to a counter-intuitive positive value in these estimates. The interacted variable which is interpreted as an adjustment to the itinerary yield parameter takes on a significant negative value. This result, indicating increased sensitivity to price differentials after 9/11 is consistent with the Alchian-Allen predictions.

Addition of route specific dummies also results in dramatically different results. The common denominator of these dummies is having either Washington area or New York City airports as a terminal point. Eastern "business" routes show a uniform significantly negative value in association with the 9/11 event. For Eastern "vacation" destinations, i.e. Florida-NYC have parameter estimates that are much smaller in absolute value, and in some cases positive. The two largest metropolitan areas in California, Los Angeles and San Francisco also have smaller parameter values. In addition, the combined West Coast and vacation destination Las Vegas has a positive parameter.

CONCLUSION

The results reported are consistent with both economic theory and expectations with one glaring exception. That exception is, of course, the estimates reflecting the major thesis of this paper, that the Alchian-Allen Theorem should result in increased first class travel relative to coach after the 9/11 events because of security screening related delays.

However, further analysis suggests that the added security measures inspired by the 9/11 terrorism did, in fact raise the fixed costs of air travel. However, the opportunity costs of newly imposed security measures are not uniform across all classes of air travelers. The fixed costs of these delays will be larger for individuals whose value of time is large, presumably the demographic most likely to travel first class. Thus, the statistical results reported may be, in fact, consistent with a more sophisticated analysis of the Alchian-Allen phenomena. Estimates of the different income elasticities among air fare classes is lacking. It is clear that income elasticity is substantial, above 1.8 for all United States air travelers, and increasing with flight distance (IATA, 2008, p.9.) There is also some indication of income stratification in selection of fare class (Hitzik, 2015.)

Another potential explanation for the apparent decline in first class travel after 9/11 is that business people resorted to non-public modes of air travel. The General Aviation statistics available from US DOT do not support this interpretation. Two different series are reported, the number of General Aviation aircraft and the flight hours of these aircraft. In addition, the statistics are reported across a variety of categories of which the most significant for the thesis are corporate, business, and personal use. During

the fifteen year period from 1994 through 2008, there was a generally positive trend in ownership of GA aircraft. In the class most relevant to thesis, corporate owned GA craft, 9/11 induced a negative trend.

Of greater relevance, the hypothesis of a shift from airlines to GA transportation suggests that flight hours should be positively affected by 9/11. In fact, only the trend estimate for corporate flight hours with a 9/11 dummy included achieves statistical significance, and this trend is negative. Thus business responses to 9/11 appear not to have resulted in replacing a public transportation mode with the private alternative.

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APPENDICES

APPENDIX 1
FARE CLASS DEFINITIONS

C	Unrestricted Business Class
D	Restricted Business Class
F	Unrestricted First Class
G	Restricted First Class
U	Unknown
X	Restricted Coach Class
Y	Unrestricted Coach Class

APPENDIX 2
SUMMARY STATISTICS FOR QUARTERLY OBSERVATIONS

Panel A		
Fare Class	**Quantity**	**Itinerary Yield per mile**
Restricted Coach Class	674392.9 (261922.3)	.1698723 (.0095375)
Unrestricted Coach Class	6053269 (701941.2)	.3714438 (.0634675)
Restricted First Class	312180.8 (146459.1)	.2144987 (.0922003)
Unrestricted First Class	186410.8 (94320.95)	.2681665 (.0743543)
Restricted Business Class	10307.15 (5450.001)	.1308258 (.0308911)
Unrestricted Business Class	14187.6 (3673.343)	.4113276 (.1173049)
Panel B		
Ratio	**Quantity**	**Itinerary Yield per mile**
Restricted First Class/ Restricted Coach Class	.05054 .02216	1.2703 .5546
Unrestricted Coach Class/ Restricted Coach Class	.1157 .0544	2.2025 .4364
Unrestricted First Class/ Restricted First Class	.6305 .1872	.7837 .1879
Observations		
Standard Deviation below Mean values		

APPENDIX 3
THE EFFECT OF 9/11 ON FIRST CLASS VERSUS COACH AIRLINE TRAVEL

Variable name		
Constant	.1269 (.0057)	.1263 (.0058)
Restricted first class yield per mile/ Restricted coach class yield	-.0512 (.0034)	-.0509 (.0034)
Terror911	-.0251 (.0037)	----
Yield911	----	-.0301 (.0045)
Number of obs	40	40
F(2, 37)	138.60	135.65
R-squared	0.8822	0.8800
Adj R-squared	0.8759	0.8735

APPENDIX 4
SUMMARY STATISTICS FOR BINOMIAL LOGIT VARIABLES

Variable	**Mean**	**Standard Deviation**	**Range Maximum**	**Range Minimum**
Dependent Variable	.05025	.2185	1	0
Itinerary yield	.1629	.2072	56.0077	**0**
Coupons	3.3317	1.1756	**20**	**0**
Passengers	2.3722	14.5900	**5143**	**0**
Distance	2998.077	1822.471	21887	**21**
Terror911 = 0 before 9/11 =1 after	.4790	.4996	1	0
Yield911=Terror 911* Itinerary Yield	.0775	.1585	31.2542	0

APPENDIX 5 PANEL A
BINOMIAL LOGIT SAMPLE: TOP 50 METROPOLITAN ORIGIN

Variable	Restricted Coach = 0 Restricted First = 1	Restricted Coach = 0 Restricted First = 1 (New York and Washington route dummies)
Constant	-1.9794 .01640	-1.7576 .0166
Itinerary yield	-.3314 .0219	-.0529 .0183
Coupons	-.3048 .0037	-.2659 .0038
Passengers	.0038 .0002	.0036 .0002
Distance	-.0000681 2.66e-06	-.000128 2.79e-06
Terror911	.3324 .0121	.3450 .0122
Atlanta-NYC		-1.2852 .0263
Boston – NYC		-1.8737 .0366
Chicago – NYC		-1.3545 .0256
Washington – Atlanta		-1.386 .0206
Washington – Boston		-1.5028 .0376
Washington – NYC		-1.8737 .0366
Fort Lauderdale – NYC		-.1882 .0233
Orlando – NYC		-.5347 .0247
Tampa – NYC		-.1582 .0193
Las Vegas – NYC		.1153 .0250
Los Angeles – NYC		.3517 .0093
San Francisco – NYC		-.1385 .0147
Estimation	**Diagnostics**	
Observations	1,625,190	1,625,190
Log likelihood	-316440.89	-303960.53
LR chi2(d.f.) **Prob > chi2**	14754.01 (13) **0.0000**	39714.74 (25) **0.0000**
Pseudo R^2	0.0228	0.0613

Note: 24500 failures and 0 successes completely determined.
All independent variables have p-values equal to zero up to 4 decimal places.

APPENDIX 5 PANEL B:
BINOMIAL LOGIT YIELD 911 ESTIMATES

Variable	Restricted Coach = 0 Restricted First = 1	Restricted Coach = 0 Restricted First = 1 (New York and Washington route dummies)
Constant	-1.7417 .0143	-1.4863 .0145
Itinerary yield	-.3153 .0037	.1411 .0165
Coupons	-.3048 .0037	-.2786 .0037
Passengers	.0037 .0002	.0035 .0002
Distance	-.0000668 2.59e-06	-.000128 2.77e-06
Yield911	-1.0888 .03409	-.8919 .0348
Atlanta-NYC		-1.3013 .0263
Boston – NYC		-1.8721 .0366
Chicago – NYC		-1.3481 .0256
Washington – Atlanta		--1.3651 .0206
Washington – Boston		-1.4872 .0376
Washington – NYC		-1.706 .0369
Fort Lauderdale – NYC		-.1827 .0233
Orlando – NYC		-.5496 .0246
Tampa – NYC		-.1642 .0193
Las Vegas – NYC		.08616 .0250
Los Angeles – NYC		.3407 .0093
San Francisco – NYC		-.1591 .0147
Estimation	**Diagnostics**	
Observations	1,625,190	1,625,190
Log likelihood	-316298.4	-303988.03
LR chi2(d.f.) **Prob > chi2**	15038.99 (13) **0.0000**	39659.73 (25) **0.0000**
Pseudo R^2	0.0232	0.0612

Note: 24500 failures and 0 successes completely determined.