WORKING PAPERS

Slow Market Adjustment to Tax Changes:
Evidence from the Market for Used Wide-body Commercial Aircraft

Loren Smith

WORKING PAPER NO. 289

May 2007

BUREAU OF ECONOMICS
FEDERAL TRADE COMMISSION
WASHINGTON, DC 20580

Slow Market Adjustment to Tax Changes: Evidence from the Market for Used Wide-body Commercial Aircraft

Loren K. Smith[1]

May 8, 2007

Abstract

Investment tax credits are generally implemented to stimulate investment in new goods. However, in the case of durable goods, such policies may also affect secondary markets for used goods. Using a simple theoretical model, I show that an exogenous shock to the price of new durable goods (e.g., a change in tax policy) causes an increase in price and a decrease in the number of transactions in used good markets. After describing the theoretical model and its predictions, I use transaction and price data for new and used wide-body commercial aircraft to show that the data is qualitatively consistent with the predictions of the theoretical model. Given a 10 percent increase in the price of new goods, the price of used goods increases 15-20 percent, and used goods are kept longer on average before they are sold in secondary markets.

[1] I would like to thank Paul Sullivan, Keith Brand, Dan Hosken and Simon Anderson for their helpful comments and suggestions. The opinions expressed in this paper are those of the author and do not necessarily represent those of the FTC or its individual commissioners. Correspondence: Federal Trade Commission, 601 New Jersey Ave., Washington, DC 20001. Email: lsmith2@ftc.gov.

1 Introduction

Investment tax credits are often designed to stimulate investment in new goods. However, tax programs may also affect secondary markets for used durable goods. This paper characterizes the effects of exogenous changes in the prices of new durable goods on prices and holdings. In 1986, a 10 percent tax credit given to purchasers of new commercial aircraft was removed, which effectively increased price of new aircraft. I use a simple theoretical model to predict the effect that such a price change in the new good market will have on markets for used durable goods, and then show that the data is consistent with the theory using price and probit regression models.

In this work, I use the theoretical model to show that an investment tax credit, such as the one removed by the Tax Reform Act of 1986 (TRA86, hereafter), not only affects investment in new durable goods, but also affects prices and quantities sold of used durable goods. Specifically, the theoretical model shows that when the price of new durable goods increases, the price of used durable goods should increase as well, but to a lesser extent. Furthermore, under the assumption that the density of consumer tastes for newness is upward sloping, owners of durable goods are more likely to hold a good for a longer period after the price of new goods increases, than they were before the price increase.

The model developed here is a simplification of richer models like those developed in Rust (1985) and Konishi and Sandfort (2002). The theoretical framework used is very similar to those employed by Anderson and Ginsburgh (1994) and Hendel and Lizzeri (1999). I assume that durable goods are useful for only two periods, and that the only source heterogeneity among goods is the physical depreciation of a good in its first and second periods of use. That is, all new goods are homogeneous and all goods physically depreciate at the same rate. Thus, all used goods are also homogeneous as well. Equilibrium with positive quantities of both new and used goods results because of heterogeneity in consumers' preferences for quality (newness), and transaction costs. Using a similar model, Hendel and Lizzeri (1999) identifies the extent to which "lemons" exist in used goods markets as compared to heterogeneity in the physical depreciation of different brands of goods. Specifically, they find that Japanese automobiles hold their value better in used markets than their American counterparts because they degrade less quickly, and not because of the existence of relatively more lemons among American automobiles. Anderson and Ginsburgh (1994) use a similar framework to characterize the ability of manufactures to (second-degree) price discriminate against consumers of used goods by altering the durability of their products.

Using transaction data from Back Aviation solutions and price data from Avmark Incorporated, I use this exogenous shock to the price of new durable goods to show that the data qualitatively supports the predictions of the theoretical model. First, I specify a price regression to show that the exogenous increase in the price of new durable goods brought on by TRA86 results in a smaller but significant increase in the price of used goods. Second, I estimate two Probit regression equations that show that transactions of used aircraft slow after the implementation of TRA86, which is consistent with the theoretical model's prediction that owners of used aircraft will hold their assets longer after an increase in the relative price of new goods.

2 Tax Reform Act of 1986

Prior to the Tax Reform Act of 1986 (TRA86 hereafter), purchasers of new capital assets, like aircraft, received an investment tax credit (ITC) of 6-10 percent. The tax credit was 10 percent for all wide-body commercial aircraft. This 10 percent discount was designed to spur investment in new durable goods. TRA86 brought about three significant changes that could impact investment by airlines in new commercial aircraft, (1) it eliminated the 10 percent ITC on the purchase of new aircraft, (2) it increased the length of time over which depreciation benefits are realized on aircraft from five to seven years from when they are new, and (3) it reduced the corporate tax rate from 46 percent to 34 percent. The first two changes instantly increased the cost of owning new aircraft relative to used aircraft. The third change reduced airlines' tax burden, which could possibly increase investment in aircraft (both new and used). This paper predicts and estimates the effects of the increase in the relative price of new aircraft on equilibrium prices and quantities in the used market.

3 Model

The following simple two-period model illustrates how, under certain assumptions, prices and quantities of used durable goods sold change with an exogenous shock to the price of new durable goods.

3.1 Information

Let there be an arbitrarily large number of time periods indexed $t = 1, 2, ..., T$. Durable goods are useful for at most two periods. Therefore, at time *t*, there are at most 2 vintages of a good in the market. At the beginning of each time period, consumers know the quality of new goods and the condition of used goods carried over from the previous period. The only source of heterogeneity across goods is deterioration from aging. Therefore, all goods of the same vintage are homogeneous. Given the price of new goods, equilibrium prices and owners of used goods are determined by a perfectly competitive market for used goods.

The market consists of manufacturers, consumers, and scrappers. The focus of this study is on dynamics and equilibrium in used markets. Therefore, manufacturer and scrapper behavior is greatly simplified and treated as exogenous (and known to consumers).

3.2 Scrappers

Scrappers have an infinitely elastic demand for all vintages of durable goods at a fixed price $\underline{P}$. In other words, they are always willing to purchase any amount of any vintage of the good at a price of $\underline{P}$ per unit. For simplicity, and without loss of generality, I set $\underline{P} = 0$.

3.3 Manufacturers

The price of a new good, P_t, is exogenously determined at time *t* by manufactures. Manufacturers provide as many new goods as are demanded at P_t. The stock of used goods available to airlines at time *t* is determined by the number of new goods demanded at time *t*-1. The location of all new and used goods and the prices of used goods are then determined by equilibrium.

3.4 Consumers

Consumers are indexed $i = 1, ..., N$. I assume the number of consumers in the market is arbitrarily large and constant over time. Consumers can own at most one durable good in each period. At time *t*, one year-old goods have quality $q_{t-1} = \nu$, and new goods have quality

$q_t = \nu + k$.[2] Consumer *i*'s preference for quality is measured by the parameter θ_i. Consumer preferences, θ_i, are distributed *F* with associated density *f* such that $f > 0$ everywhere on the relevant support.

The utility received by consumer *i* at time *t* is determined by the good they own when they enter the period (if they own one), the good they choose in the current period (if they choose one), and the prices of new and used goods. As is shown in Anderson and Ginsburgh (1994), if there are no changes in the quality of new or used goods (i.e., ν and k), or in the price of new or scrapped goods, over any two-period span there are only four choices that can possibly be optimal for consumers (for simplicity, I assume the discount factor is zero):

1. Consumer *i* buys a new good and sells a used good in each period:

$$V_i(n,n) = 2\left[\theta_i(\nu + k) - P_n + P_u - c\right],$$

where *c* is a transaction cost associated with purchasing a good.

2. Consumer *i* buys a new good and holds it for two periods:

$$V_i(n,u) = \theta_i(2\nu + k) - P_n - c.$$

3. Consumer *i* buys a used good in each period:

$$V_i(u,u) = 2\left[\theta_i \nu - P_u - c\right].$$

4. Finally, consumer *i* does not consume either new or used goods:

$$V_i(0,0) = 0.$$

Any combination of segments of the market defined by the above payoffs may (or may not) exist in equilibrium.

[2] I assume a deterministic rate of depreciation for durables. Previous work, e.g., Rust (1985) and Konishi and Sandfort (2002), has allowed for more general depreciation patterns. More generality in the depreciation of durables does not change the point I am illustrating with the model developed here.

3.5 Equilibrium and Some Implications

I assume that the secondary market for used goods is perfectly competitive. Equilibrium prices of used goods and the owners of new and used goods are determined by the price of new goods set by manufacturers. Characterization of all of the possible equilibria of the model is given in great detail in Anderson and Ginsburgh (1994). For this study, I will focus on equilibria where markets for both new and used goods exist, and prices of new and used goods are positive. For a secondary market for used good to exist and the price of used good be positive, the supply of used goods (i.e., those buying a new good in every period) and the demand for used goods (i.e., those buying a used good in every period) must be equal. Given the distribution of consumer tastes for quality, *F*, the equilibrium condition can be expressed

$$1-F\left(\frac{P_n-2P_u+c}{k}\right)=F\left(\frac{P_n-2P_u-c}{k}\right)-F\left(\frac{P_u+c}{v}\right). \tag{1}$$

Using the equilibrium condition given by equation (1), the following results can be derived.

Claim 1 – $0<\frac{dP_u}{dP_n}<\frac{1}{2}$

Proof – By the implicit function theorem,

$$\frac{dP_u}{dP_n}=\frac{f\left(\frac{P_n-2P_u+c}{k}\right)+f\left(\frac{P_n-2P_u-c}{k}\right)}{2\left[f\left(\frac{P_n-2P_u+c}{k}\right)+f\left(\frac{P_n-2P_u-c}{k}\right)\right]+\frac{k}{v}f\left(\frac{P_u+c}{v}\right)}$$ *, which is between 0 and 1/2.*

Claim 1 states that when the price of a new good increases \$1, the price of used goods may not increase at all, and will increase by no more than \$0.50. Given the simplicity of the theoretical model, in particular the fact that goods are only useful for two periods, the quantitative results are not too meaningful. What is more important is the qualitative result that when the price of new goods increase, the model predicts that the price of used goods will increase, but to a lesser extent.

Claim 2 – ***If the density of consumer preferences for quality, f, is increasing (decreasing), the proportion of consumers holding goods for two periods is increasing (decreasing) in the price of new goods.***

Proof – The proportion of consumers holding used goods for two periods is given by,

$H = F\left(\frac{P_n - 2P_u + c}{k}\right) - F\left(\frac{P_n - 2P_u - c}{k}\right)$, *and*

$\frac{dH}{dP_n} = \frac{1}{k}\left(1 - 2\frac{dP_u}{dP_n}\right)\left[f\left(\frac{P_n - 2P_u + c}{k}\right) - f\left(\frac{P_n - 2P_u - c}{k}\right)\right] > (<) 0$ *if the term in square brackets is positive (negative), which is true when* $f'(x) > (<) 0$ *for all x's in the relevant domain.*

Claim 2 can be interpreted to mean that as the density of consumers with a high preference for quality becomes tighter and/or the density of consumers with a low preference for quality becomes more dispersed, the proportion of consumers holding goods for two periods will more likely increase when the price of new goods increases. This observation provides some insight into the market for wide-bodied commercial aircraft. In the market for wide-body jets, there are relatively few airlines that purchase the majority of new wide-body commercial aircraft, which is consistent with a tight distribution of consumers with a high preference for quality. Moreover, there are numerous purchasers of used wide-bodies that purchase aircraft at widely varying times in their lifecycle, which is consistent with a widely dispersed density of consumers with a low preference for quality. Therefore, the distribution of consumer tastes is apparently increasing and one might anticipate the number of airlines holding used aircraft for longer durations to increase if the price of new aircraft increases, *ceteris paribus*.

4 Data

In this section, I present an overview of the data. The transaction data were provided by Back Aviation Solutions (BAS), and the price data were provided by Avmark Incorporated (AI).[3]

[3] I thank Todd Pulvino at the Kellogg Business School for providing me with this data.

4.1 Transaction Data

The transaction data give detailed information about every aircraft that was registered to fly in the past 60 years at several points in each aircraft's lifecycle. Importantly for this study, the data provide a rich set of information for each aircraft in the sample when it is new and whenever it is sold in the secondary market, including the buyer and seller of the aircraft.

Although the data includes information on many types of aircraft, this study focuses on the nearly 3000 wide-body commercial aircraft active during the fifteen-year period spanning 1978-1993. The study is narrowed to wide-body jets for several reasons. First, wide-bodies are arguably the most important segment of the commercial aircraft market. Wide-body commercial jets generated more revenue in both primary and secondary markets than all other types of aircraft combined during the relevant time period. Second, wide-bodies are less likely to be substitutes for alternative types of aircraft, such as narrow body aircraft and regional jets, since during the sample period wide-body jets were used predominantly for transoceanic routes and were the only type of aircraft capable of flying routes of such lengths. Finally, narrowing my attention to wide-bodies is consistent with other studies in the literature (see e.g., Smith (2007) and Benkard (2005)).

The data provided by BAS also include several observed attributes for each aircraft. The attributes are as general as the aircraft's make and model, and as detailed as the height of the aircraft's cargo door in centimeters. Airlines carefully consider the technical specifications of an aircraft prior to purchase, and carefully monitor each aircraft's condition as it ages. Therefore it is reasonable to assume that the observed attributes of aircraft influence aircrafts' values to airlines.

4.2 Price Data

The price data include actual transaction prices for 700 of the almost 3000 new and used aircraft sold in new and used markets during the time period 1978-1993. Prior to 1993, U.S. air carriers were required by law to report the price of any new or used aircraft they purchased or sold. Therefore, most of the missing prices are for transactions involving airlines outside of the

U.S.[4] The remaining missing prices are for transactions that took place in 1993, but were reported on tax filings in 1994. Aircraft prices were reported to the Department of Transportation and/or the Federal Aviation Association and assembled by AI.

5 Empirical Framework

Using the data described above, I design some reduced form empirical models to investigate the possibility that (1) equilibrium prices of aircraft changed significantly after TRA86, and (2) that the length of time that airlines hold aircraft is affected by the change in tax structure.

5.1 Prices

The theoretical model presented in Section 3 suggests that if TRA86 increases the prices airlines pay for new wide-body aircraft, the prices of used aircraft are likely to increase as well, but to a lesser extent. To attempt to identify the extent to which TRA86 may have affected prices in the used market, I specify the following regression,

$$\begin{aligned} P_{jt} = {} & AGE_{jt}\beta_1 + AGE_{jt}^{\ 2}\beta_2 + AGE_{jt} \times DTRA86_t\beta_3 + DNEW_{jt}\beta_4 + \\ & DNEW_{jt} \times DTRA86_t\beta_5 + DUSED_{jt} \times DTRA86_t\beta_6 + X_j\beta_x + \varepsilon_{ijt}. \end{aligned} \tag{5.1}$$

The dependent variable, P_{jt}, is the natural logarithm of the observed transaction price of aircraft *j* when it was sold at time *t*. The variable *DTRA*86 is equal to one if the sale took place in 1986 or after. Recalling that the tax policy change was enacted in 1986, β_5 and β_6 measure the difference in the average price of aircraft after the policy change relative to before the policy change for new and used aircraft respectively, controlling for airplane model-specific effects (the *X's*), price declines associated with aircraft aging (*AGE*), and any differences in the price declines associated with aircraft aging before and after the policy change (β_3).

One reasonable criticism of the specification given by equation (5.1) is that the policy dummy variable simply reflects a trend in prices that occurred over the sample period that has

[4] There are over 300 airlines outside of the U.S. that owned a wide-body jet at one time or another during the sample period.

nothing to do with the policy.   Therefore, I also estimate a second specification of the regression equation given by equation (5.1) plus a linear time trend.

Another possibly misleading artifact of the data is that though the policy took effect in January of 1986, discussions of a policy change began sometime in 1985. As a result, it is unclear whether airlines' ownership behavior in 1985 was affected by the policy or not. Therefore, I also estimate a third specification of the model that throws out all sales made in 1985.

5.2 Transactions

In addition to effects on the prices of used goods, under specific assumptions about the distribution of consumer preferences for newness, the model also predicts that aircraft will more likely be held longer after the tax change than they were before the tax change. Specifically, since there are relatively few airlines purchasing the majority of new wide-body commercial aircraft, and there are many purchasers of used wide-body jets with perhaps widely varying preferences for quality (or newness), one might expect the number of airlines holding used aircraft for longer durations to increase if the relative price of new aircraft increases due to the tax change.

To evaluate this hypothesis, I estimate two Probit models. In the first specification, I use 24,618 observations (including over 3,000 sales) occurring between 1978-1993 involving aircraft ages 2-15 to estimate the parameters of the equation

$$\begin{aligned}\Pr\left(Sold_{ijt}\right) = \alpha_{it} + \sum_{k=2}^{15} 1\left(AGE_{jt} = k\right)\beta_{k-1} + \\ \sum_{k=2}^{15} 1\left(AGE_{jt} = k\right) \times DTRA86_t\,\beta_{13+k} + X_j\beta_x + \varepsilon_{ijt}.\end{aligned} \tag{5.2}$$

Since the data contain many observations and sales, I am able to estimate 142 parameters, including 10 seller-specific fixed effects, parameters for a full spline in age before and after the tax program, and aircraft characteristics and several model-vintage fixed effects (the *X*'s). $\beta_{15} - \beta_{28}$ are the parameters of interest for evaluating the hypothesis that airlines' hold used aircraft longer after the TRA86.

Again, a reasonable criticism of the specification given by equation (5.2) is that the policy dummy variable simply captures a trend in the frequency of secondary market transactions occurring over the sample period that have nothing to do with the policy. Therefore, I also estimate a Probit specification given by equation (5.2) plus a linear time trend.

Also, since discussions of a policy change began sometime in 1985, it is unclear whether airlines' ownership behavior in 1985 was affected by the policy or not. Therefore, I also estimate a third specification of the model that throws out all sales made in 1985.

Another possible criticism of the above specification is that the periods before and after the tax change are too long, and therefore, the parameters of interest are capturing period-specific effects other than those brought on by the policy change. Such concerns may be alleviated somewhat if the results are similar when the model is evaluated at points in time only soon before and immediately after the tax change.[5] Estimation of the second Probit specification uses 3,640 (about 300 sales) observations occurring in 1984 and 1986 involving aircraft ages 2-15. Sticking with the notion that the announcement of a policy change sometime in 1985 may have indirectly affected airline investment behavior in 1985, 1984 is used instead. The second Probit estimation equation is given by

$$\Pr\left(Sold_{ijt}\right) = AGE_{jt}\beta_1 + AGE_{jt} \times DTRA86_t\beta_2 + \left(AGE_{jt}\right)^2\beta_3 + X_j\beta_x + \varepsilon_{ijt}. \quad (5.3)$$

The data used for this specification contain too few observations to reliably estimate a complete spline in age and its interaction with the policy variable, like was done in the specification given by equation (5.2). Alternatively, the more parsimonious specification given by equation (5.3) is quadratic in age. The parameter that captures the effect of the policy in this specification of this model is β_2. A negative estimate of β_2 indicates that older aircraft are less likely to be sold after the policy change than they were before.

6 Results

The estimation results are generally consistent with the predictions of the theoretical model outlined in section 3.5.

6.1 Price Regression Results

[5] I would have liked to have been able to do something similar with the price regressions, but there were too few observed prices to make this possible.

To evaluate the price regressions described in Section 5.1, I use 564 sales of wide-body aircraft ages 1-15 for the first two specifications, and 501 sales of wide-body aircraft ages 1-15 for the last specification. The results of the price regressions are given in Table 6.1. Neither the addition of the time trend in Specification 2 or the exclusion of sales made in 1985 in Specification 3 seem to have a meaningful effect on the parameter estimates or the regressions' quality. Therefore, I summarize the results of all of the specifications of the price regression together. The small and insignificant coefficient on the interaction of the TRA86 and new dummy variables indicate that the transaction prices of new aircraft do not differ significantly before and after the implementation of TRA86. Therefore, accounting for the 10 percent tax credit, the price of new aircraft effectively increased approximately 10 percent after the policy was enacted in 1986. The regression results indicate that the price of used aircraft increase between approximately 15 and 20 percent after the policy took effect, after controlling for model and age effects.

The theoretical model predicts that when the price of new aircraft increase the price of used aircraft may increase but not more than half as much. However, the predictions of the theoretical model are made in level (not percentage) terms. The regression approximates the average price before TRA86 of a new Boeing 747-100 to be 64.5 million real (1982-1984) dollars (effectively $58 million after the realization of the 10 percent investment tax credit), a five year-old aircraft of the same model has a predicted average price of $36.6 million, and a 10 year-old 747-100 has a predicted average price of $25.6 million. After the implementation of TRA86 the average price of a five year-old 747-100 increases to approximately $41-42.8 million (a $5.4-7.2 million increase), and the average price of a 10 year-old 747-100 increases to $29.4-30.6 million (a $3.8-5.0 million increase). The price increases for the used models predicted by the data are higher than those predicted by the theoretical model presented in Section 3. There are a few possible explanations that may explain the under-prediction of price increases in used good markets by the theoretical model. First, the theoretical model assumes that aircraft are only useful for two periods. As the number of useful periods of the durable good increases in the theoretical model, so does the predicted price increases for used models relative to a price increase of new models. Second, the theoretical model only mimics price increases that occur due to a change in the investment tax credit. The actual TRA86 also increased the number of years over which depreciation benefits were realized by aircraft owners from the first 5 years of an aircraft's life to the first 7 years of an aircraft's life. This also increased the relative (to new aircraft) value of used aircraft.

6.2 Probit Results

The results of the first three Probit specifications are given in Table 6.2. The introduction of the time trend in the second specification does not effect the estimated correlation between the policy dummy variable and the probability of an aircraft being sold in the used market *qualitatively*; however the time trend does affect the magnitude of the estimated correlations. The coefficient estimates on the interactions of the age dummy variables and the policy dummy variable (a dummy variable that equals one in 1986 and after) indicate that airlines are generally more likely to hold used aircraft longer after the implementation of TRA86. Specifically, in Specification 1, almost all of the coefficients are negative and most are significant. On average (across different ages of aircraft), the policy decreases the probability an aircraft will be sold in used markets by approximately 3 percent. The results are similar for Specification 2, but the magnitude and statistical significance of the results are reduced. Specification 3 excludes transactions made in 1985, since the announcement of the policy may have affected airline behavior even before the policy was put in place. Though none of the coefficients on the interaction of the policy variable and various aircraft ages differ statistically between Specifications 2 and 3, it does appear that the point estimates of Specification 3 are slightly more negative, indicating that given the exclusion of data from 1985, the Probit model predicts a more significant estimated dampening of secondary market transactions after TRA86 was put in place. The only non-negative (though insignificant) coefficient on the policy interactions in all of the specifications presented in Table 6.2 is on the interaction of seven year-old aircraft with the TRA86 dummy. This is likely a result of the fact that the depreciation schedule for commercial aircraft was extended from five to seven years by TRA86, which might have made seven years a new focal point for the sale of a used aircraft. The results of the first set of Probit regressions also indicate that longer aircraft and aircraft with greater fuel capacities are more likely to be sold in used markets, while longer range aircraft are more likely to be held by their current owners. Also, the fact that Eastern and Northwest airlines tend to keep aircraft relatively longer before selling them in used markets is reflected in the relatively large and negative coefficients on their respective dummy variables.

The results of the final Probit specification, which focuses on aircraft holdings in the years 1984 and 1986, are given in Table 6.3. The results of the regression further support the idea that used aircraft sales slowed after the implementation of TRA86. Specifically, the negative and significant coefficient on the interaction of age and a dummy variable for observations in 1986 indicates that used aircraft of every age from 2 to 15 are less likely to be sold in 1986 than they were in 1984.

The results of the Probit regressions presented above are consistent with the predictions of the theoretical model if the density of consumer tastes for quality (newness) is increasing. This is consistent with the notion that all buyers have different tastes for quality and the fact that there are very few buyers buying the majority of new aircraft, while there are many buyers of used aircraft. This is appears to be true in the data. New aircraft are often bought several at a time, and over 80 percent of new aircraft are purchased by 20 airlines, while there have been over 300 owners of used wide-body aircraft within the relevant time period.

7 Conclusions

The theoretical model characterized above, as well as the price and discrete choice regression models estimated in this paper are designed to show that an investment tax credit like the one removed by TRA86 not only affects investment in new durable goods, but also affects prices and quantities of aircraft held in used durable good markets. Specifically, the simple theoretical model shows that when the price of new durable goods increases, the price of used durable goods should increase to a lesser extent. Furthermore, under the assumption that the density of consumer tastes for quality is upward sloping, owners of durable goods are more likely to hold a good for two periods after the price of new goods increases, than they were before the price increase.

The results of the theoretical model are generally consistent with the data on sales of used wide body aircraft. The price regression model shows that the average transaction price of used aircraft increases approximately 15-20 percent after the implementation of TRA86. In addition, the two Probit regression models developed in the paper show that transactions of used aircraft generally slow after the implementation of TRA86. This supports the prediction of owners of used aircraft holding their assets longer after the implementation of TRA86 than they did before.

References

[1] Anderson, S. P., and V. P. Ginsburgh (1994), "Price Discrimination via Second-hand Markets," European Economic Review, 38, 23-44.

[2] Benkard, C. L. (2004), "A Dynamic Analysis of the Market for Widebodied Commercial Aircraft," Review of Economic Studies, 71:3.

[3] Hendel, I., and A. Lizzeri (1999), "Adverse Selection in Durable Goods Markets," American Economic Review, 89:5, 1097-1115.

[4] Konishi, H., and M. T. Sandfort (2002), "Existence of Stationary Equilibrium in the Markets for New and Used Durable Goods," Journal of Economic Dynamics & Control, 26, 1029-1052.

[5] Rust, J. (1985), "Stationary Equilibrium in a Market for Durable Assets," Econometrica, 53:4, 783-805.

[6] Smith, L. K., (2006), "Dynamics and Equilibrium in a Structural Model of Commercial Aircraft Ownership," FTC Working Paper No. 280.

Table 6.1

Log Price Regression

Age and Vintage Parameters

Variable	Specification 1	Specification 2	Specification 3
Constant	**3.7258*** (0.1909)	**3.7798*** (0.1995)	**3.8139*** (0.2022)
New	**0.1150** (0.1597)	**0.1199** (0.1598)	**0.3891** (0.2639)
$DNew \times DTRA86$	**-0.0129** (0.1507)	**0.0140** (0.1535)	**-0.2208** (0.2649)
$DUsed \times DTRA86$	**0.1471*** (0.0753)	**0.1774*** (0.0820)	**0.1967*** (0.0908)
Age	**-0.1000*** (0.0146)	**-0.0982*** (0.0148)	**-0.0957*** (0.0158)
$Age \times DTRA86$	**0.0090** (0.0071)	**0.0084** (0.0071)	**0.0146** (0.0085)
Age^2	**0.0019*** (0.0008)	**0.0019*** (0.0008)	**0.0014** (0.0010)
Time	**NA**	**-0.0065** (0.0070)	**-0.0119** (0.0074)

$n = 564$ for Spec. 1 and Spec. 2, $n = 501$ for Spec. 3;
$R^2 = 0.8409$ for Spec. 1, $R^2 = 0.8411$ for Spec. 2 and $R^2 = 0.8390$ for Spec. 3;
* - indicates significance at the 5 percent level

Table 6.1
Log Price Regression
Aircraft Model Parameters

Variable	Specification 1	Specification 2	Specification 3
747-100	**0.3515** (0.1852)	**0.3106** (0.1903)	**0.3152** (0.1937)
747-200	**0.4707*** (0.1807)	**0.4449*** (0.1828)	**0.4330*** (0.1849)
747-Special	**0.0183** (0.1917)	**-0.0084** (0.1938)	**-0.0651** (0.1980)
747-400	**0.7554*** (0.1784)	**0.7542*** (0.1784)	**0.7533*** (0.1801)
767-200	**-0.0146** (0.1808)	**-0.0261** (0.1813)	**-0.0325** (0.1832)
767-300	**0.1087** (0.1762)	**0.1036** (0.1763)	**0.0998** (0.1780)
DC10-100	**-0.2234** (0.1834)	**-0.2588** (0.1873)	**-0.2550** (0.1896)
DC10-200	**0.1789** (0.1808)	**0.1520** (0.1833)	**0.1170** (0.1854)
DC10-300	**-0.2926** (0.2294)	**-0.3243** (0.2320)	**-0.2749** (0.2353)
MD11	**0.4559*** (0.2024)	**0.4650*** (0.2027)	**0.4725*** (0.2047)
L-1011-1	**-0.5610*** (0.1842)	**-0.5915*** (0.1871)	**-0.5518*** (0.1897)
L-1011-503	**-0.4506*** (0.1896)	**-0.4755*** (0.1915)	**-0.7733*** (0.2343)
L-1011-500	**-0.2114** (0.1859)	**-0.2306** (0.1870)	**-0.2835** (0.1897)
L-1011-200	**-0.1686** (0.2280)	**-0.1754** (0.2280)	**-0.1857** (0.2304)
A300-B220	**-0.1339** (0.2171)	**-0.1669** (0.2200)	**-0.1900** (0.2224)
A300-B410	**-0.1596** (0.1816)	**-0.1791** (0.1828)	**-0.1995** (0.1849)
A300-C4	**-0.2693** (0.3027)	**0.2991** (0.3041)	**-0.3313** (0.3073)
A310-200	**0.0174** (0.2523)	**-0.0100** (0.2540)	**-0.0313** (0.2570)
A310-220	**-0.0164** (0.2062)	**-0.0309** (0.2069)	**-0.0482** (0.2090)
A310-300	**-0.0521** (0.1927)	**-0.0450** (0.1929)	**-0.0433** (0.1950)

* - indicates significance at the 5% level.

Table 6.2

Probit Model 1
Characteristics and Airline Specific Effects

Variable	Specification 1		Specification 2		Specification 3	
	Coefficient	**Marginal Effect**	**Coefficient**	**Marginal Effect**	**Coefficient**	**Marginal Effect**
Constant	**-2.1396***	**NA**	**-10.2422***	**NA**	**-10.0423***	**NA**
	(0.1620)		(0.6650)		(0.6832)	
Fuel Capacity	**4.46e-06***	**3.88e-07***	**4.71e-06***	**2.73e-07***	**4.61e-06***	**2.68e-07***
	(1.36e-06)	(1.19e-07)	(1.41e-6)	(8.28e-07)	(1.46e-06)	(8.62e-08)
Range	**-1.62e-05**	**-1.14e-06**	**-1.67e-05**	**-9.67e-07**	**-1.86e-05**	**-1.08e-06**
	(1.23e-05)	(1.07e-07)	(1.25e-6)	(7.26e-07)	(1.30e-05)	(7.60e-07)
Length	**0.0040***	**0.00034***	**-0.0036***	**-0.00021***	**-0.0032**	**-0.00019**
	(0.0015)	(0.00013)	(0.0017)	(0.0001)	(0.0018)	(0.0001)
Eastern Airlines	**-0.9216***	**-0.0383***	**-0.9344***	**-0.0241***	**-1.0509***	**-0.0249***
	(0.1602)	(0.0024)	(0.1634)	(0.0018)	(0.1855)	(0.0017)
TWA	**-0.3628***	**-0.0233***	**-0.3666***	**-0.0151***	**-0.3579***	**-0.0149***
	(0.1156)	(0.0052)	(0.1156)	(0.0033)	(0.1254)	(0.0036)
Delta Airlines	**0.1975***	**0.0201***	**0.2074***	**0.0145***	**0.2208***	**0.0157***
	(0.0804)	(0.0094)	(0.0818)	(0.0068)	(0.0839)	(0.0071)
USAir	**-0.1661**	**-0.0126***	**-0.2332***	**-0.0109***	**-0.1894***	**-0.0092***
	(0.0906)	(0.0059)	(0.0939)	(0.0035)	(0.0962)	(0.0039)
United Airlines	**-0.1681***	**-0.0128***	**-0.1934***	**-0.0094***	**-0.1825***	**-0.0090***
	(0.0834)	(0.0055)	(0.0829)	(0.0034)	(0.0845)	(0.0035)
Continental Airlines	**0.2417***	**0.0257***	**0.2324***	**0.0168***	**0.2495***	**0.0184***
	(0.1085)	(0.0139)	(0.1085)	(0.0096)	(0.1110)	(0.0101)
American Airlines	**-0.2403***	**-0.0173***	**-0.2502***	**-0.0116***	**-0.2551***	**-0.0118***
	(0.0872)	(0.0051)	(0.0877)	(0.0032)	(0.0907)	(0.0033)
Northwest Airlines	**-0.7621***	**-0.0358***	**-0.7731***	**-0.0227***	**-0.7923***	**-0.0229***
	(0.1368)	(0.0028)	(0.1362)	(0.0019)	(0.1393)	(0.0020)
Piedmont Airlines	**0.4190***	**0.0513***	**0.4174***	**0.0369***	**0.4005***	**0.0338***
	(0.0802)	(0.0130)	(0.0816)	(0.00098)	(0.0879)	(0.0102)
Time	**NA**	**NA**	**-1.2811***	**-0.0743***	**-1.2377***	**-0.0719***
			(0.0945)	(0.0037)	(0.0966)	(0.0039)

Also included in the probit models summarized by this and the following table were dummy variables for every model-vintage combination (e.g., Boeing 747 that was new in 1985, Boeing 767 that was new in 1986, etc.).
N = 24618 -- * - indicates significance at the 5 percent level

Table 6.2

Probit Model 1
Aircraft Age Effects Before and After 1986

Variable	Specification 1		Specification 2		Specification 3	
	Coefficient	Marginal Effect	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Age = 3	-0.7580*	-0.0387*	1.4354*	0.2417*	1.4172*	0.2366*
	(0.0986)	(0.0027)	(0.1986)	(0.0562)	(0.2028)	(0.0569)
4	-0.6266*	-0.0347*	2.8401*	0.7319*	2.6989*	0.6876*
	(0.0932)	(0.0031)	(0.2820)	(0.0795)	(0.2890)	(0.0882)
5	-0.5434*	-0.0318*	4.1987*	0.9616*	4.0576*	0.9524*
	(0.0896)	(0.0033)	(0.3716)	(0.0216)	(0.3804)	(0.0276)
6	-0.5203*	-0.0309*	5.4961*	0.9900*	5.2575*	0.9883*
	(0.0915)	(0.0035)	(0.0915)	(0.0025)	(0.4758)	(0.0037)
7	-0.6705*	-0.0358*	6.6203*	0.9925*	6.2651*	0.9917*
	(0.1066)	(0.0032)	(0.5603)	(0.0013)	(0.5726)	(0.0015)
8	-0.4682*	-0.0288*	8.1011*	0.9943*	7.8384*	0.9942*
	(0.0998)	(0.0042)	(0.6517)	(0.0011)	(0.6657)	(0.0011)
9	-0.3080*	-0.0213*	9.5465*	0.9957*	9.2166*	0.9956*
	(0.0991)	(0.0053)	(0.7450)	(0.0009)	(0.7617)	(0.0010)
10	-0.2223*	-0.0163*	10.9087*	0.9963*	10.5615*	0.9962*
	(0.1015)	(0.0062)	(0.8387)	(0.0008)	(0.8571)	(0.0009)
11	-0.2603*	-0.0186*	12.1457*	0.9966*	11.7344*	0.9963*
	(0.1097)	(0.0062)	(0.9335)	(0.0008)	(0.9548)	(0.0009)
12	-0.0257	-0.0022	13.6623*	0.9968*	13.1639*	0.9963*
	(0.1097)	(0.0092)	(1.0281)	(0.0008)	(1.0518)	(0.0009)
13	-0.0926	-0.0075	14.8691*	0.9968*	14.4838*	0.9964*
	(0.1226)	(0.0092)	(1.1238)	(0.0008)	(1.1512)	(0.0009)
14	-0.0778	-0.0064	16.1554*	0.9965	15.8372*	0.9963
	(0.1432)	(0.0110)	(1.2200)	(0.0008)	(1.2518)	(0.0009)
15	0.1352	0.0131	17.6525*	0.9959	17.277*	0.9956
	(0.1608)	(0.0173)	(1.3156)	(0.0009)	(1.3525)	(0.0009)
2*DTRA86	-1.5960*	-0.0468*	-0.3758*	-0.0157*	-0.4280*	-0.01717*
	(0.1142)	(0.0016)	(0.1454)	(0.0045)	(0.1463)	(0.0042)
3*DTRA86	-0.4171*	-0.0260*	-0.1435	-0.0073	-0.2231	-0.0106
	(0.1335)	(0.0057)	(0.1335)	(0.0060)	(0.1367)	(0.0053)
4*DTRA86	-0.3801*	-0.0244*	-0.1389	-0.0071	-0.1400	-0.0072
	(0.1248)	(0.0056)	(0.1250)	(0.0056)	(0.1311)	(0.0059)
5*DTRA86	-0.3853*	-0.0246*	-0.1847	-0.0091	-0.2278	-0.0108
	(0.1265)	(0.0056)	(0.1260)	(0.0052)	(0.1329)	(0.0051)
6*DTRA86	-0.3883*	-0.0247*	-0.2353	-0.0110	-0.2240	-0.0106
	(0.1314)	(0.0058)	(0.1305)	(0.0049)	(0.1400)	(0.0054)
7*DTRA86	0.0596	0.0054	0.1744	0.0118	0.2648	0.0195
	(0.1283)	(0.0123)	(0.1285)	(0.0101)	(0.1380)	(0.0126)
8*DTRA86	-0.1081	-0.0086	-0.0246	-0.0014	-0.0685	-0.0037
	(0.1204)	(0.0088)	(0.1206)	(0.0067)	(0.1281)	(0.0066)
9*DTRA86	-0.0702	-0.0058	-0.0102	-0.0006	-0.0320	-0.0018
	(0.1139)	(0.0088)	(0.1143)	(0.0065)	(0.1221)	(0.0067)
10*DTRA86	-0.2555*	-0.0181*	-0.2144	-0.0102	-0.2601	-0.0120
	(0.1190)	(0.0067)	(0.1198)	(0.0046)	(0.1282)	(0.0046)
11*DTRA86	-0.0742	-0.0061	-0.0372	-0.0021	-0.0627	-0.0034
	(0.1192)	(0.0092)	(0.1202)	(0.0065)	(0.1340)	(0.0069)
12*DTRA86	-0.5095*	-0.0294*	-0.4831*	-0.0182*	-0.4598*	-0.0178*
	(0.1233)	(0.0043)	(0.1245)	(0.0029)	(0.1416)	(0.0034)
13*DTRA86	-0.4559*	-0.0274*	-0.4272*	-0.0169*	-0.5580*	-0.0199*
	(0.1325)	(0.0051)	(0.1340)	(0.0034)	(0.1566)	(0.0031)
14*DTRA86	-0.5213*	-0.0298*	-0.4907*	-0.0184*	-0.7367*	-0.0227*
	(0.1503)	(0.0051)	(0.1526)	(0.0034)	(0.1793)	(0.0026)
15*DTRA86	-0.6259*	-0.0329*	-0.5945*	-0.0203*	-0.8402*	-0.0238*
	(0.1637)	(0.0045)	(0.1661)	(0.0030)	(0.2166)	(0.0025)

2 year-old aircraft prior to 1986 are the comparison group. N = 24618
Standard errors are in parentheses -- * - indicates significance at the 5 percent level

Table 6.3

Probit Model 2
Includes Data for Only 1984 and 1986

Variable	Coefficient	Marginal Effects
Constant	-1.1879* (0.1636)	NA
Fuel Capacity	6.99e-06* (2.46e-06)	8.75e-07* (3.08e-08)
Range	8.33e-06 (2.49e-05)	1.04e-07 (3.12e-06)
Length	-0.0017 (0.0025)	-0.0002 (0.0003)
$Age \times D1984$	-0.0583 (0.0391)	-0.0073 (0.0049)
$Age \times DTRA86$	-0.0902* (0.0410)	-0.0113* (0.0051)
Age^2	0.0077* (0.0022)	0.00097* (0.00027)
Boeing 747	-1.7667* (0.3009)	-0.1941* (0.0342)
Boeing 767	-1.0910* (0.2167)	-0.0697* (0.0064)
Airbus A-300	-0.5586* (0.1694)	-0.0515* (0.0113)
Douglas DC-10	-1.0846* (0.2236)	-0.0922* (0.0138)
Lockheed L-1011	-0.9145* (0.2013)	-0.0707* (0.0095)

The comparison group is Airbus A-310.

$n = 3460$; $\log - likelihood = -883.20$; $\chi^2(11) = 186.52$

* - indicates significance at the 5 percent level