Estimating the impact of investment tax credits on aircraft demand

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Abstract

This paper uses exogenous price changes from the shifting tax policies of the 1980's to identify the parameters of a nested-logit discrete choice model of the aircraft market. The federal Investment Tax Credit (ITC) was a tax credit of 6-10% of a firm's new capital investment that was removed by the Tax Reform Act of 1986 (TRA86). Such tax credits continue to be proposed as tools to spur investment, and they are still utlized in many states and select industries. This research adds to the small body of empirical work on taxes in imperfectly competitive markets. I model the oligopoly market structure of aircraft manufacturers by assuming Bertrand competition. The demand-side parameters are estimated using 2SLS with cost-shifting instruments. The demand-side choices are purchasing new or used aircraft, or refraining from purchasing an aircraft. I then estimate linear mark-up equations using the demand-side parameter estimates and other cost variables. I use the full set of parameter estimates to simulate aircraft transactions before and after the TRA86. This structural approach allows me to isolate the effects of the ITC through counterfactual policy simulations. I find that the ITC encourages firms to upgrade to more expensive capital by purchasing a more expensive aircraft than they would have without the ITC; however, the ITC has very limited impact enticing firms to purchase new aircraft instead of used aircraft. The overall effect on new purchases is small. Thus, most of the incidence of the tax credit was gained by the suppliers of aircraft; moreover the ITC exacerbated the market power of suppliers, leading to further distortions.

Keywords: Subsidy, TRA86, Differentiated Products, Aircraft

JEL: H25, L13, L93

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1. Introduction

The Tax Reform Act of 1986 (TRA86) was the largest change in the tax code since the introduction of the federal income tax in 1913 (Pechman 1987). This paper studies the effects of this and other tax changes on the demand for commercial aircraft from 1978 through 1991. Estimation of demand before and after large exogenous events, specifically the Economic Recovery Act of 1981 (ERTA) and the TRA86, will identify the demand-side parameters. I estimate a nested-logit discrete choice model of the aircraft market in order to evaluate the incidence of removing the Investment Tax Credit (ITC) the model is also used to measure the change in consumer surplus.

The federal ITC was an immediate tax credit of 6 – 10% of the cost of firms' capital investment. During the period covered by the data, the ITC for aircraft was either 0, 7% or 10%. The corporate tax rate and depreciation schedule for commercial airplanes also changed during this period. Although it was removed over 20 years ago, studying the effects of the ITC remains relevant given continued debate over tax policy. Investment tax credits remain an active policy tool for both state and federal authorities. Investment tax credits are, or have recently been, utilized in all US states.[1] Examples of contemporary state investment tax credits include the Colorado Enterprise Zone ITC and Virginia's Historic Rehabilitation Tax Credit. State ITCs tend to be narrowly focused. Unlike the broad ITC associated with the pre-TRA86 era, the federal government currently utilizes targeted investment tax credits similar to state credits. The IRS offers tax credits for refurbishing historic landmarks; solar, geothermal, or fuel cell energy capital investments; and gasification of coal. President Obama proposed a small business tax credit to expand employment and suggested "a tax incentive for all businesses...to invest in new plants and equipment."[2] Despite their prevalence, investment tax credits remain both politically and economically contentious. Goolsbee (1998) quotes a congressman in 1969 questioning whether the government subsidy lowered prices for capital investment or simply raised profits for capital manufacturers. This question remains important today given the Obama Administration's potential investment tax proposals.

The ITC was first introduced in 1962 as a countercyclical tax policy to stimulate demand (Feldstein 1983). The ITC was in effect until 1969, when it was eliminated; however, in 1971 the tax credit was re-instated. In 1975, the ITC was temporarily raised from 7% to 10%, for most goods. This change to 10%

[1] Internet search of state government web pages.
[2] State of the Union address January 27, 2010.

was made permanent for most assets in 1978 (Gravelle 1994).[3] The 10% ITC was maintained under ERTA, the large tax cuts initiated after Reagan was elected. ERTA's primary effect was acceleration of the depreciation allowance (Jorgenson and Yun 1990). With regard to corporate taxation, TRA86 had three major elements. First, it substantially reduced the statutory marginal tax rate faced by corporations from 46% to 34%. Second, the act standardized the length of depreciation schedules across capital, including aircraft.[4] Finally, and of greatest interest for this study, TRA86 removed the ITC. Seven years later the Clinton Administration proposed new corporate tax changes, including an increase in the marginal tax rate to 35% and a 7% ITC. The Clinton Administration's ITC proposal had complex eligibility requirements that would have, among other constraints, required a minimum threshold of investment before a tax-payer was eligible for the credit (Willens and Phillips 1993). While the corporate marginal tax rate was raised to 35%, the proposed new ITC was not enacted.

There has been much research on the effect of the ITC and TRA86. TRA86 has been studied in the labor market, in the asset market, and in general equilibrium simulations. However, an industry-specific empirical study has never been performed. Data for such studies is rarely available. The elimination of the ITC represents a major change in the cost of investment that remains relevant in understanding the industry-specific impact of corporate taxation.

I use a data set recording commercial aircraft transaction in the U.S. between 1978 and 1991 to estimate the effect of tax policy on aircraft purchases and prices. I model aircraft supply using the Berry-Levinsohn-Pakes formulation of monopolistic competition, so that the incidence of a tax subsidy like the ITC will depend not only on marginal costs and elasticities of demand but also on the degree of market power of producers. Using counterfactual simulations, I find that the ITC can have a modest positive impact on new aircraft sales. However, I also find that any positive impact on aircraft sales is substantially mollified by existing market power. Producers with substantial market power are able to manipulate consumers' demand curves through control of substitute good pricing.

This paper will proceed with an industry description in Section 2 followed by a literature review in Section 3. Next will be the model in Section 4, the data in Section 5, and the estimation and some intuitive elasticities in Section 6. Section 7 discusses model simulation and Section 8 presents the counterfactual results. Section 9 concludes.

[3] The ITC for commercial aircraft was maintained at 7% until 1981.

[4] Depreciation rates for tax purposes vary across assets. Commercial aircraft depreciation rates were changed from five years to seven years; this change is incorporated in my analysis.

2. Industry Description

In this section I will describe several important features of the commercial aircraft industry, which is a source of major economic activity.[5] My data set offers unusually specific insight into the substitution pattern among various new and used aircraft types and the effects of the ITC.

While there are many customers, the commercial aircraft industry has few manufacturers. As of 2011 there were only three manufacturers of commercial jet aircraft with 100+ passenger capability: Boeing, Airbus, and Embraer.[6] During the time covered by my data – 1978 through 1991 – there were never more than six manufacturers: Airbus, Boeing, British Aerospace, Fokker, Lockheed, and McDonnell Douglas.[7]

Commercial aircraft are typically divided into two groups: wide-body and narrow-body. Wide-body aircraft are large jet aircraft with large cabins. If a wide-body is configured to carry passengers, then multiple aisles divide passenger seats. The first wide-body aircraft was the Boeing 747 which first flew in 1969. The 747 was soon followed by the McDonnell Douglas DC-10 and the Lockheed L-1011 TriStar, both in 1970. Airbus, a consortium of European companies, launched the A300 wide-body in 1972. The range capability of wide-body aircraft is not consistent across makes or models. Some wide-body aircraft have extremely long range while others have only moderate range capabilities. This leads to a natural subdivision within the wide-body group of commercial aircraft into long and short ranges.

The other commercial aircraft group is the narrow-body group. Narrow-bodies are smaller jets with smaller cabins than those of wide-bodies. When designed for passenger travel, narrow-body aircraft have only one aisle dividing seats. The first commercial jet, the de Havilland Comet in 1952, could be considered a small narrow-body aircraft. Boeing and Douglas entered the narrow-body market in 1958 and 1959, respectively, and continued to manufacture narrow-body aircraft throughout my data set. Airbus, British Aerospace, and Fokker entered the narrow-body market in the 1980's. Interestingly, Lockheed never produced a narrow-body commercial jet. The range capabilities of narrow-body aircraft, just as with wide-body aircraft, vary across models and can be separately grouped as long-range and short-range. Figure 1 shows the firm participants in the wide- and narrow-body market from 1978 through 1991.

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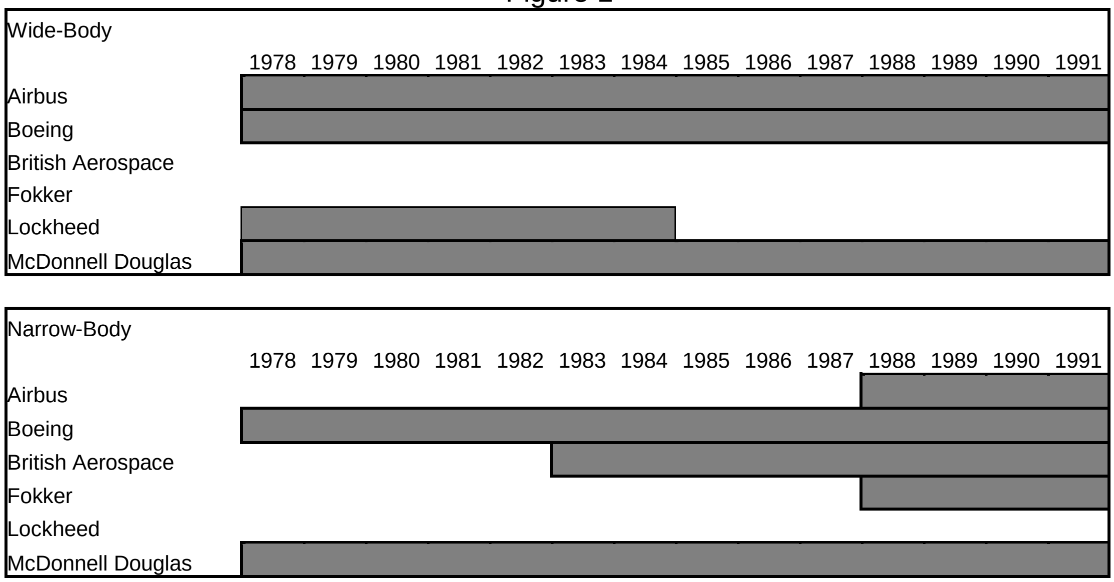
[5] Total US commercial aircraft revenue in 1997 was $40 billion.

[6] This excludes Russian Ilyushin, Tupolev and Yakovlev aircraft, which have not been utilized extensively for Western commercially applications.

[7] The British Aircraft Corporation BAC-111, manufactured from 1965-1989, has been omitted. While the BAC-111 could be configured for up to 119 passengers, typical configuration was for 89 passengers. Only 20 units were manufactured from 1978-1989.

Figure 1



Aircraft in the long-range category have longer range capabilities than aircraft in the short-range category respective to their other wide-body or narrow-body counterparts. Aircraft are, occasionally, given nomenclature such as ER for “extended range.” For classification purposes, aircraft within the wide- and narrow-body categories which share the range characteristics of a manufacturer-identified “extended,” or “long,” range aircraft are placed into the long-range category. Long-range wide-body aircraft have strictly longer range than any other category. This might lead one to alternatively think of long-range narrow-body aircraft as being “medium range”: longer range than other narrow-body aircraft, but not as long range as wide-body long-range aircraft. However, this is somewhat misleading as many long-range narrow-body aircraft have considerably longer range than some short-range wide-body aircraft even as other long-range narrow-body aircraft have less range capability than some short-range wide-body aircraft. Table 1 shows the average range and passenger capacity of aircraft in my data set as grouped in these categories.

Wide-body aircraft are typically used for long-haul high volume routes. Wide-body aircraft significantly reduced per-seat operating cost for air-carriers and opened up significant international markets when introduced. Sales of wide-bodies have steadily increased since their introduction. In the late 1990’s, the sale of new wide-body aircraft accounted for approximately 60% of manufacturers' revenue and 30% of units sold (Smith 2010). The enormous share of revenue is also associated with high manufacturers' profits. Irwin and Pavcnik (2004) report that Boeing’s 747 sales have comprised up to 33% of Boeing’s accounting profits in certain years.

Table 1

	Range in 1000's of km.		Passengers	
	Mean	s.d.*	Mean	s.d.*
Wide-body Long-Range	14.6	0.66	427	87.7
Wide-body Short-Range	9.8	1.54	390	54.6
Narrow-body Long-Range	6.7	3.03	182	38.1
Narrow-body Short-Range	3.9	0.66	132	25.6

*This is the population's standard deviation

Narrow-body aircraft tend to be used for shorter routes. Nevertheless, some more modern narrow-body aircraft are capable of trans-Atlantic flights. Short-range narrow-body aircraft are typically used for regional jet traffic. While narrow-body aircraft often do not hold as many passengers, nor have the same range capability as wide-body aircraft, they are not inferior products. Airbus and Boeing continue to introduce aircraft with shorter ranges and smaller passenger capacities to fill niche markets. Often narrow-body aircraft are used in high flight-frequency routes such as on the US East Coast. The substitutability of aircraft models between groups is not always straightforward. The wide-body Airbus A300 models, variants of which are still produced today, have an average range of 7,542 km, while the narrow-body Douglas DC-8 models, the last of which was produced in 1972, have an average range of 12,198 km. This indicates that many different parameters are necessary to characterize demand for the diverse aircraft on the market from 1978-1991.

It is important to consider the ordering and production cycle. Typically, aircraft are ordered one or more years in advance. The price for an aircraft is contracted when the order is placed and the purchaser makes non-refundable pre-delivery payments at regular intervals until 30% of the aircraft's gross price is pre-paid; the balance of the payment is due at delivery.[8] Order cancellations are unusual but do occur. Until the late 1990's air-carriers did not enter into exclusive purchasing agreements with manufacturers. Most air-carriers purchase an assortment of aircraft makes and models. Most orders are for multiple copies of the same aircraft; however, some orders are for only one model. American Airlines, operator of the world's largest commercial fleet, uses Airbus, Boeing, and McDonnell Douglas aircraft. Included in American Airlines' fleet are both the Boeing 737 and McDonnell Douglas MD-80 series.[9] The Boeing 737 and McDonnell Douglas MD-80 were designed to compete with each other and are close substitutes. This indicates that there are not strong airline-producer unobservable effects in my data. While the

[8] The only exception to this is when an aircraft order is canceled and another firm decides to purchase the "white tale," as such unordered production is termed, in place of another aircraft that was scheduled for later delivery. That is, a firm takes delivery of an aircraft early because one becomes available.
[9] American Airlines website, AA.com.

aircraft market clearly involves dynamic elements, I will make some simplifications to keep the model tractable.

Many economists believe that the aircraft industry faces falling marginal costs while keeping prices relatively constant. Benkard (2004 and 2000), Irwin and Pavcnik (2001), Tyson (1992), and Baldwin and Krugman (1988) utilize models in which marginal costs fall as production increases. For example, Benkard (2000) finds that Lockheed priced the TriStar L-1011 below its static marginal cost. Lockheed pursued this otherwise pathological strategy in hopes of reaching a lower, and profitable, marginal cost at a future date. Alternatively, Baldwin and Krugman (1988) posit that aircraft manufacturers price by using marginal cost in a more classical sense; nevertheless, the marginal cost in their model falls. It typically takes about 400 units of sales to re-coup the development cost (Carbaugh and Olienyk 2001). I treat firms' pricing decisions as reflecting their anticipated long run marginal costs, and not dynamically changing marginal costs. The relationship between current marginal cost and the marginal cost against which a manufacturer prices will be further discussed in Section 4.

Used aircraft are an important component of the commercial aircraft market. Commercial aircraft are a massive long-lived investment. The life expectancy of a typical wide-body aircraft is 25-35 years (Smith 2010). This allows for an evolving stock of used aircraft. The market treats used aircraft as a substitute for new aircraft. From 1978-1991 there were 1,402 separate sales of 2,581 different used aircraft versus 1,193 sales of 2,764 new aircraft. The data demonstrates that used wide-body and narrow-body aircraft are substitutes for new versions of their respective types. While many used aircraft transactions in the data are from a major airline to a minor airline, at least 42% of used commercial aircraft sales were to major airlines.[10,11]

3. Literature Review

3.1 Aircraft Industry

A sample of recent literature involving the aircraft industry includes Baldwin and Krugman (1988), Benkard (2000, 2004), Irwin and Pavcnik (2004), and Smith (2010). My model of the aircraft industry most closely follows Irwin and Pavcnik (2004).

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[10] The federal government categorizes a major airline as one that generates at least $1 billion in revenue.

[11] The data set denotes some aircraft as being sold to a leasing company. The data does not indicate the end user, which may have been a major airline. The financial arrangements that govern purchase should have little impact on demand estimation unless an air-carrier both purchased and leased the same aircraft in the same quarter. There is no evidence of this behavior.

Baldwin and Krugman (1988) study the competition between US and European aircraft manufacturers. They calibrate a Cournot model with dynamically falling marginal costs of production. Interestingly, Baldwin and Krugman seek to measure the change in surplus from direct government subsidies. They limit the scope of the model to studying the market for the Boeing 767 and the Airbus A300. They argue that the airline industry may enjoy increasing returns to scale and might benefit from consolidation. Their study has limited empirical foundation, and they acknowledge, "It is difficult to place policy conclusions on our results."

Benkard (2000) studies the production side of the commercial aircraft market. He estimates the learning, forgetting, and spillover effects of manufacturing commercial aircraft. He utilizes a unique cost data set for the Lockheed L-1011 TriStar and finds that Lockheed frequently priced below static marginal cost in order to reduce their long-run costs through learning-by-doing. He also finds evidence of institutional forgetting and incomplete spillovers between the long-range and short-range versions of the L-1011. Benkard (2004) models a dynamic oligopoly with both demand and supply estimates. He uses estimated parameters to explain entry and exit of products. Benkard's dynamic model helps explain why Lockheed continued to price below cost over the entire 250 unit production run of the L-1011. His model allows for simulating the changes in consumer surplus under alternative regulatory schemes.

Smith (2010) estimates a dynamic equilibrium model of demand for new and used wide-body commercial aircraft. In each period airlines select one or more new or used aircraft. His paper finds equilibria in both the primary and secondary markets. Smith (2010) simulates an equilibrium with a 10% ITC, and finds such a credit would cause only a small increase in domestic aircraft ownership. He concludes that a 10% ITC would have minimal effects on the substitution between new and used aircraft.

Irwin and Pavcnik (2004) study the effect of trade negotiations on the commercial aircraft market. They estimate a nested-logit model of demand and markup pricing equations. After they have estimates, they perform policy simulations for changes in trade policy and for the entry of the A380 "super-jumbo" jet. My estimation approach closely follows Irwin and Pavcnik's for reasons I explain as I detail my model; however, my data set includes both narrow- and wide-body aircraft and I focus on domestic tax policy. Importantly, mine is the only aircraft paper that considers the sizable difference between the pre- and post-tax price of an aircraft.

3.2 Theoretical Models of Tax Incidence

The ITC was a tax credit awarded to agents that invested in new capital.[12] In the aircraft industry, the purchaser of the aircraft received the tax credit and therefore gained the statutory incidence. The economic incidence falls on the agent that gains real income. The question of the economic incidence of tax subsidies, including TRA86 specifically, depends on the underlying demand elasticities and market structure.

There is much theoretical work on tax incidence across market structures. Fullerton and Metcalf (2002) find that taxes can be "over-shifted." Over-shifting means that price changes by more than 100% of the tax. This result is only possible in imperfectly competitive markets. Poterba (1984) models owner-occupied housing as an asset market which exploits favorable tax treatment. His paper is representative of literature that models the effects of taxes in competitive markets with dynamic capital accumulation. Poterba is of particular interest in my research because he revisited the housing market after TRA86 tax changes were incorporated (Poterba 1990), and his simulation indicates that TRA86 lowered the deadweight loss in the housing market. The ITC was an *ad valorem* subsidy. This makes Delipalla and Keen's (1992) study of the different tax incidence of per-unit and *ad valorem* taxes in oligopoly markets particularly relevant. They show that a hypothetical revenue-neutral change from a per-unit to an *ad valorem* tax induces an increase in production. Delipalla and Keen use a conjectural variation approach for homogenous-products oligopolies.[13] They find that tax incidence, and the ability to pass forward taxes, differs considerably between *ad valorem* and per-unit taxes. Hamilton (1999) builds on Delipalla and Keen by focusing on tax efficiency in symmetric homogenous-product oligopolies. He finds that the abilities to pass forward and over-shift taxes are much higher with per-unit taxes than *ad valorem* taxes. His approach relates changes in efficiency to supply elasticity. In cases where there is no supply curve, the supply curve is analogous to the horizontal summation of the marginal cost curves associated with all of the firms in the market. Hamilton's result is particularly interesting when one considers the possible policy goals of the ITC and targeted investment tax credits in general. Luca Bossi (2008) builds on Hamilton's work by investigating the welfare effects of per-unit versus *ad valorem* taxes with a dynamic

[12] The ITC had very limited applicability to used capital. The credit could be taken for no more than $120,000 of the cost of capital for a total credit of $12,000. This amount should not have an empirically important impact in the aircraft industry.

[13] Conjectural variation is the modeling of firm *j*'s "dynamic" reaction to changes in quantity by firm $i \neq j$. Functionally the models are usually written as modified FOCs $p(Q)+(1+\lambda)q_i p'(Q)-c'(q_i)=0$, where $(1+\lambda)={}^{dQ}/_{dqi}$ is the conjectural variation. Such models are theoretically unattractive because they model a dynamic game as being a static game (Tirole 1988).

monopoly. Bossi finds a region of elasticities in which the *ad valorem* tax has a greater negative impact on welfare than a per-unit tax.

Theoretical work on tax incidence in differentiated-product oligopoly is an active field. Anderson, et al. (2001) find that differentiated-product oligopoly markets behave very similarly to homogenous oligopoly markets with respect to tax incidence. The supply elasticity has a similar effect on tax incidence and over-shifting in both differentiated- and homogenous-product market structures. A sample of literature which builds on Anderson, et al. includes Kind, et al. (2008) which finds that the tax incidence in double-sided markets is shifted and can be over-shifted, in the same ways described above.[14]

While my findings support the theoretical results related to production changes and over-shifting under *ad valorem* versus per-unit taxes, my model is not well related to the theoretical tax incidence models detailed above. The theoretical literature's results are depend on producer's increasing marginal costs and I model producers as having fixed marginal costs. Given the theoretical ambiguity, determining tax incidence under imperfect competition remains an empirical question

3.3 Empirical Models of Tax Incidence

To the best of my knowledge, there are five earlier papers that utilize structural modeling and tax changes to estimate parameters. Four of these papers utilize structural modeling to estimate tax incidence in production markets: Karp and Perloff (1989), Barnet, Keeler, and Hu (1995), Devereux and Lanot (2003), and Fershtman, Gandal, and Markovich (1999). In addition to the incidence work, Christian Rojas (2008) uses tax changes to study the market structure of the US brewing industry.

Karp and Perloff (1999) estimate both tax incidence and market structure in the Japanese television market. They estimate demand by imposing constant elasticity of substitution utility functions across different television types. Karp and Perloff separately estimate cost functions and interact the cost and demand parameters in order to estimate a conjectural variation parameter and theoretically calculate tax incidence. While this approach is attractive because of the similarity in the oligopoly market structure, they have considerably more data on which to base their supply side estimation. Karp and Perloff assume a high degree of homogeneity inappropriate for the aircraft industry.

[14] A double-sided market is one in which a firm services both "sides." The credit card industry is a classic example: earning revenue from retailers and interest from consumers.

Barnett, Keeler, and Hu (1995) estimate the incidence of cigarette excise taxes. They estimate a reduced-form aggregate demand curve, a reduced-form retail pricing equation, and a trans-log cost equation. The parameters are then used to estimate the oligopoly conjectural variation parameter in a non-linear model and simulate the application of additional taxes. Both of these first two papers require cost data not readily available for the aircraft industry.

Rojas (2008) uses a large exogenous tax change to identify the parameters in a Deaton and Muellbauer Almost Ideal Demand System. Rojas and I share the use of price changes from tax policy to identify our models. He compares alternative hypothetical market structures -- Bertrand-Nash, Stackelberg, collusion -- and rejects collusion as not fitting the data.

Devereux and Lanot (2003) use data from the UK housing market to study the incidence of taxes and subsidies in an oligopoly market where two different mortgage types are available. Devereux and Lanot impose supply side symmetry, where every supplier of mortgage loans is identical; moreover, they must assume a zero marginal cost of providing mortgages. Their model is narrowly specialized for the UK mortgage market.

In approach, my research is most similar to Fershtman, Gandal, and Markovich (1999). They employ a Berry, Levinsohn, and Pakes (1995) type structural estimation approach for automobiles in Israel and simulate the effect of tax changes on both the supply and demand sides of the market.

3.4. The Investment Tax Credit

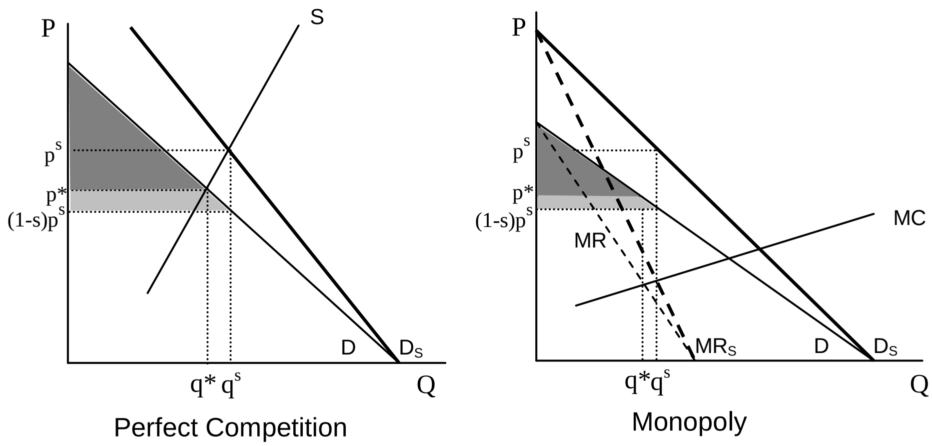
In the early 1980's economists at the US Treasury spent 10 months developing a comprehensive tax reform proposal that came to be known as Treasury I (McLure and Zodrow 1986). This tax reform proposal was intended to alter the tax system so as to "interfere with private decisions as little as possible" (Auerbach and Slemrod 1997). After some modification, Treasury I went on to become the Tax Reform Act of 1986 (TRA86), the largest change in the tax code since the introduction of the federal income tax in 1913 (Pechman 1987).

Goolsbee (1998) is an example of empirical tax incidence investigation in capital markets. Moreover, Goolsbee specifically studies the incidence of the ITC. He shows that, with some exceptions, prices of capital goods fluctuated with the ITC. They rose when the ITC rose and fell when the ITC was lowered and again when the ITC was removed. Goolsbee uses changes in the ITC to proxy for changes in demand in a reduced-form estimation approach. He finds a price increase of between 3½% - 7% for most industries in response to a 10% ITC. His findings indicate that, on average, about 60% of the subsidy goes to buyers and 40% goes to the manufacturers of capital. He concludes that capital is supplied along an upward sloping supply curve. Goolsbee's approach differs from much of the macro-oriented capital investment literature. The macro literature generally ignores capital manufacturers and focuses on adjustment costs of capital. They typically find that adjustment costs stymie investment incentive policies. Typically, price elasticities of investment are estimated as being both low and lagged. Cummins, Hassett, and Hubbard (1996) is an exception to this finding. Using countries' exogenous tax changes, they find that adjustment costs are only between 5%-10%. That is, they find that the capital cost would rise by no more than 1% with the introduction of a 10% ITC. This is in stark disagreement with Goolsbee's claim that the ITC "simply create[d] short-run windfall gains for capital suppliers."

Although my model uses theoretically grounded structural demand curves for aircraft, similar to Fershtman, Gandal, and Markovich (1999), it is, in its dealing with the ITC, most similar to Goolsbee's reduced-form paper. Goolsbee shows the empirical fact that an increase in tax credits for capital investment causes an increase in the price of capital; however, his methodology assumes that markets are perfectly competitive. Most manufacturers of capital, including the aircraft industry, are better characterized as imperfectly competitive.

Modeling capital markets as perfectly competitive misses much of the welfare implications of the ITC's removal. Figure 2 shows that near-identical changes in the observed price and quantity in a market can have dramatically different welfare implications. Goolsbee's market structure assumptions are captured by the left side diagram in Figure 2. The right side diagram depicts a monopoly market that has similar price and quantity changes. The left and right side show the considerable differences in consumer surplus between the two market structures. The dark grey regions show the non-subsidy consumer surplus and the light shaded regions show the post subsidy consumer surplus in the two market structures. The aircraft industry is an oligopoly, and reduced-form estimation, such as Goolsbee's, that does not consider market structure will have very different welfare implications. Additionally, aircraft are durable goods; as discussed already, consideration must be given to the market for used aircraft.

Figure 2



4. Model

I model the market for commercial aircraft as a differentiated products market. This is consistent with the contemporary literature on aircraft, which I reviewed earlier (Benkard 2004, Irwin and Pavcnik 2004, Smith 2010). Typical models have a discrete choice form in which each customer purchases one unit of a good (Berry 1994, Berry, Levinsohn, and Pakes 1995). While many smaller firms order only one aircraft, large commercial airlines have been known to order 20+ aircraft at once. Regrettably, a discrete choice model that allows for multiple purchases, such as Hendel (1999), requires unavailable customer-specific data on fleet composition. I do not have data for all aircraft customers including airlines, freight forwarders, and charter services. Other challenges that I discussed earlier include the “built to order” nature of the market, advanced pricing before the actual cost of the aircraft is known, and the falling marginal cost of production as is widely posited (Benkard 2004 and 2000, Irwin and Pavcnik 2001, Tyson 1992, Baldwin and Krugman 1988). No single paper deals with all of these issues. Ultimately, as in the related papers mentioned above, I crafter a compromise in which each aircraft sold was treated as a separate transaction. That is, regardless of the number of aircraft that may have been sold in one transaction, each aircraft transaction is treated as a separate sale.

4.1. Demand

The commercial aircraft market is comprised of *M* individual air-routes between airports.[15] Each period, exogenous profit maximizing air-carriers maximize their utility using the Berry (1994) random utility

[15] This is similar to Chiliberto and Tamer (2009), who define a market as "the trip between two airports." I extend from their definition to define the total market size, M, as the total number of such trips.

framework.[16] Air-carriers choose an aircraft, *j*, from a set of all new and used aircraft, *j=1,…,J*, for air-route *i*, where *i=(1,…M).* Air-carriers may also choose not to select an aircraft for an air-route; this creates a so-called outside option, *j=0*, in which an air-carrier gets more utility from not purchasing than from purchasing an aircraft.

Each aircraft *j*, *j=1,…,J*, is modeled as a bundle of characteristics including price, passenger capacity, maximum takeoff weight, and range. The outside option is modeled as providing zero utility. This setup is similar to that used by Irwin and Pavcnik (2004).

The utility from selecting aircraft type *j* for air-route *i* in period *t* is given by $u_{ij} = x_j\beta + \alpha\tilde{p}_j + \xi_j + \nu_{ij}$, where x_j is a vector of the aircraft *j's* aforementioned characteristics, $\tilde{p}_j$ is the aircraft's after tax price, $\tilde{p}_{jt} = p_{jt} \bullet (1+\tau_t)$, α and the vector β are parameters to be estimated, and ξ_j and ν_{ij} are the random parts of utility.[17,18] A time subscript is implicit, since both the pre- and post-tax prices change over time. ξ_j is an unobserved, by the economist, characteristic of aircraft *j* in period *t*. This unobserved attribute is the same for all customers. Also, ξ_j is orthogonal to x_j. This is a common assumption used for estimating Berry-type share equations. This orthogonality assumption allows airlines to value a particular model aircraft more than is captured by the descriptive characteristics -- a Boeing might be valued more than an Airbus -- provided that characteristics aren't restricted to particular models: all Boeings have longer range, more passenger capacity, etc. The aircraft industry is consistent with this assumption. The error ν_{ij} is aircraft *j's* unobserved match value for air-route *i*. For example, a Boeing 747 might be a good fit for a long range coast-to-coast route and a poor fit for a short range commuter-type route. The valuation of ν_{ij} would be high in the first case and low in the second case. The logit model requires that ν_{ij} be distributed iid extreme value. This means that if a hypothetical air-carrier were to purchase five 747 aircraft at the same time, then five draws of $\nu_{i,747}$ were realized in such a way as to make the 747 the highest utility alternative for five air-routes. The realization of such a vector of ν_{ij}*'s* is plausible if air-carriers focused on certain types of air-routes. While some air-carriers do focus on specific types of air-routes, this

[16] Technically the air-carrier is a firm and I am deriving their factor demand curves; therefore, I derive demand from maximized profits and not utility. For consistency with earlier literature I will treat air-carriers as utility maximizing agents in the generic sense. A manufacturer's cost minimization problem is functionally identical to an agent's expenditure minimization problem. This technicality has no impact on the result.

[17] $\tilde{p}_{jt} = p_{jt} \bullet (1+\tau_t)$ is used for *consistency within the literature*, the final "tax rate," τ, is actually a net subsidy and might more properly be written as $\tilde{p}_{jt} = p_{jt} \bullet (1-s_t)$

[18] The statutory incidence of the ITC and appropriate depreciation allowances are on the air-carrier; therefore it is appropriate to model the consumer as facing the lower after-tax price.

remains an uncomfortable assumption.[19] Nevertheless, as with Irwin and Pavcnik (2004) and Benkard (2004), data restrictions preclude a more sophisticated modeling approach.

Aircraft j is selected for air-route i if it provides higher utility than any other option $u_{ij} \geq u_{ik}$ $j \neq k$. The outside option, $j=0$, reflects circumstances in which no aircraft would provide utility for the associated air-route. If ν_{ij} is independently and identically distributed extreme value, this gives the probabilistic demand share for aircraft j as

$$s_j = \frac{e^{\delta_j}}{\sum_k e^{\delta_k}}$$

where $\delta_j \equiv x_j \beta + \alpha \tilde{p}_{jt} + \xi_j$, is the mean utility for aircraft j. This demand share, s_j, multiplied by the total number of air-routes, M, yields the quantity of aircraft type j sold, $s_j \cdot M = q_j$.

This type of share equation creates well-known unsatisfactory substitution patterns between aircraft types, where incumbent aircraft demand absorbs the demand for aircraft that are removed from the market based on the incumbents' relative market share. This is of particular importance given market entry and exit as presented in Figure 1. In order to mitigate this substitution pattern, aircraft are nested into segments.

I group aircraft into mutually exclusive market segments, or groups, $g=1,\ldots,8$. The groups are

- New long-range wide-body aircraft,
- New short-range wide-body aircraft,
- New long-range narrow-body aircraft,
- New short-range narrow-body aircraft.
- Used long-range wide-body aircraft,
- Used short-range wide-body aircraft,
- Used long-range narrow-body aircraft,
- Used short-range narrow-body aircraft.

These categories, by somewhat different names, are regularly used in the airline industry, as noted earlier. This makes the substitution patterns dependent on pre-defined aircraft nests in which an agent is more likely to purchase a substitute aircraft within the same nest.

[19] The idiosyncratic valuation for aircraft j by customer i, $\nu_{i,j}$, would – in the case of multiple unit purchases of the same aircraft by the same customer – either be identical to one another $\nu_{i,j} = \nu_{i+1,j}$ or sandwiched between the neighboring two idiosyncratic errors: $\nu_{i+1,j+1} < \nu_{i+1,j} < \nu_{i+1,j-1}$. The former case would be a probability zero event in this model, and the latter is inconsistent with the iid requirement of the logit model.

Following Berry (1994), the error v_{ij} can be decomposed into $v_{ij} = \zeta_{ig}+(1-\sigma)\varepsilon_{ij}$, where ζ has a density function that depends on σ and is common to all aircraft in group g. The parameter σ, $0 \le \sigma < 1$, closely associated with correlation, indicates how easily aircraft within a group can be substituted for each other. If $\sigma=0$, the demand exhibits no measured grouping, or nesting, across aircraft types; if $\sigma=1$, then aircraft are not substitutable across nests.

The within nest share equation is given by

$$\bar{s}_{j|g}(\delta,\sigma) = \frac{e^{\delta_j/(1-\sigma)}}{D_g}, \text{ where } D_g \equiv \sum_{k\in g} e^{\delta_k/(1-\sigma)} .$$

The group share equation is given by

$$\bar{s}_g(\delta,\sigma) = \frac{D_g^{(1-\sigma)}}{\sum_{g=0}^{4} D_g^{(1-\sigma)}},$$

so this gives the market share for any aircraft as

$$s_j(\delta,\sigma) = \bar{s}_{j|g}\cdot\bar{s}_g = \frac{e^{\delta_j/(1-\sigma)}}{D_g}\cdot\frac{D_g^{(1-\sigma)}}{\sum_{g=0}^{4} D_g^{(1-\sigma)}} .$$

Inverting and rearranging the share equation, one gets the Berry-type linear estimation equation:

$$\ln s_j - \ln s_0 = x_j\beta + \alpha\tilde{p}_j + \sigma \ln \bar{s}_{j|g} + \xi_j .$$

This log-linear estimation equation regresses the monotonically transformed share of an aircraft, lns_j-lns_0, on the characteristics of the aircraft x_j, the price of an aircraft p_j and the likelihood of an aircraft being selected should a particular group be selected $lns_{j|g}$. For example, this tells us that, as α is negative, the share would increase if the price was lowered. The estimation equations have an unobserved quality term ξ_j associated with each aircraft. This error is likely correlated with the price, and therefore requires an instrument for estimation. Also, the share equations contain a within group share for aircraft j: $\bar{s}_{j|g}$. The presence of the within group variable creates a simultaneity problem. I use both a cost-shifting instrument for aircraft prices and, following the BLP approach, I use characteristics of other aircraft as instruments for the within-group share. The characteristics of competing aircraft should be correlated with aircraft j's within-group share and aircraft j's price, while not being correlated with the aircraft j's own unobservable cost error ξ_j.

4.2. Pricing Equations

As mentioned in the industry section, aircraft manufacturers are widely believed to face decreasing marginal costs with increasing quantity (Benkard 2004 and 2000, Irwin and Pavcnik 2001, Tyson 1992, Baldwin and Krugman 1988). The literature on the aircraft market suggests that manufacturers face a learning curve. This model does not consider the precise path of cost gains from any future lower marginal cost levels from production life-cycle. Properly modeling dynamic marginal costs would require considerable product level cost data which is not available. Rather, this model assumes that the markup equations utilize an aircraft's "target" marginal cost.

Aircraft manufacturers likely experience learning-curve-type cost-lowering effects, and manufacturers anticipate all of these cost-lowering benefits. I assume that manufacturers price aircraft based on future anticipated marginal cost. This assumption is consistent with Benkard's (2000, 2004) finding that prices are stable even as costs vary considerably. That is, this model implies that manufacturers fully expect the future learning-curve reductions in marginal cost, and consequently firms price using *anticipated* marginal cost in order to compete with substitute products from other manufacturers that may have already lowered marginal cost via production. Pricing below static marginal cost for early units of production can be thought of as a necessary sunk cost. In this model marginal cost $\tilde{c}_j$ should be considered the target marginal cost and $\tilde{\pi}_{ft}$ the marginal profits.

Following Irwin and Pavcnik (2004), the aircraft industry is modeled as though it competes in price, though they omit taxes. Moreover, with respect to the above mentioned notion of marginal cost, each aircraft's cost is assumed to be independent of the quantity produced. This creates an approach very similar to Fershtman, et al (1999). Marginal cost is assumed to be linear in characteristics. Marginal cost is given as

$$\tilde{c}_j = w_j \gamma + \theta_j \,,$$

where w_j is a vector of characteristics, θ_j is an aircraft-specific unobserved cost error, and γ is a vector of parameters to be estimated.[20] As one might expect, w_j will have many, though not all, of the same components as x_j.

Each manufacturer f, f=1,…,6 , maximizes after-tax marginal profits.

[20] Alternative cost functions, such as the log cost function used in BLP, could be estimated.

$$\tilde{\pi}_{ft} = \sum_{j \in \Im_{ft}} \left[p_{jt} - \tilde{c}_j \right] \cdot q_{jt}$$
,

where p_{jt}, q_{jt}, and $\tilde{c}_j$ are the price, quantity and cost of aircraft *j* in period *t*, respectively, and taxes will be incorporated as appropriate.[21] Note that manufacturer *f* produces aircraft *j* in period *t* if *j* is in *f*'s production set $\Im_{ft}$. $\Im_{ft}$ has as many aircraft as the manufacturer produces in period *t*: $j=1,\ldots,J_{ft}$. In this marginal profit equation q_{jt} is the total number of aircraft *j* that have been sold in period *t*. If per-aircraft profits are constant, the profit function can be rewritten as dependent on s_j:

$$\tilde{\pi}_{ft} = \sum_{j \in \Im_{ft}} \left[p_{jt} - \tilde{c}_j \right] \cdot s_j \, .$$

While there exists a lag between order and delivery, the price contracted in the period when an aircraft is ordered reflects the expected valuation of the aircraft in the period in which its delivery is scheduled. Price is dependent on both the cost and anticipated market structure at the time of delivery.[22] Additionally, aircraft manufacturers receive a great majority of remuneration upon delivery. These factors contribute to mitigate the order-in-advance nature of the aircraft industry. Both the data and airline personnel suggest that there is *not* substantial non-linear pricing in aircraft.[23]

Each firm solves J_{ft} first-order conditions, one for each aircraft it manufactures. And, each firm's first-order condition will consider the effect of price changes on the other aircraft produced by that firm, as captured by the second term here:

$$s_j + \sum_{k \in \Im_{ft}} [p_{kt} - \tilde{c}_k] \cdot \frac{\partial s_k}{\partial p_{jt}} = 0$$

Following Verboven (1996) as presented in Fershtman, et al. (1999), the pricing equation for a product is given as

$$p_{jt} = \frac{\tilde{p}_{jt}}{(1+\tau_t)} = w_j \gamma - \frac{(1-\sigma)}{\alpha(1+\tau_t)[1-\sigma\sum_{h \in g_f} \bar{s}_{h|g}(\delta,\sigma) - (1-\sigma)\sum_{h \in g_f} s_h(\delta,\sigma)]} + \theta_j$$

where $\bar{s}_{j|G}(\delta,\sigma)$ is the within-group share, $s_j(\delta,\sigma)$ is the overall share, and θ_j is an unobserved, by the economist, aircraft-specific cost error. α and σ are from the share equation estimation. Note that the summations in the denominator are over other aircraft produced by that same firm and sold in that group.

[21] Note that after the manufacturers maximizes profits, any marginal tax rate will be "divided out" of the maximization problem. Changes in the marginal tax rate should not affect *p*. I cannot track any changes in the ITC or the depreciation rate that might alter the *manufacturers'* pricing decision.
[22] For example, the impending release of the Airbus A380 undoubtedly impacted the price of Boeing 747s scheduled for delivery contemporaneous with the A380.
[23] American Airlines fleet management office.

For example, if aircraft *j* were the Boeing 747 – a long-range wide-body aircraft – the pricing equation summation would include the Boeing 747, extended range 767-200ER, and the extended range 767-300ER; these three aircraft comprise the set of Boeing's long-range wide-body aircraft for several years.

5. Data

5.1 Data Source

I have a panel of new and used commercial aircraft transactions eligible for commercial use in US airspace from January 1978 through December 1991. Avmark Inc., an aviation-consulting firm, assembled these data. Avmark utilized reported transaction prices for aircraft sales to and from US firms. All aircraft prices and transaction dates are given for 2,764 separate new aircraft sales from six different manufacturers to 58 different domestic owners. Avmark also reports 256 international prices and transactions dates for new aircraft to an additional 64 international customers. Finally, used aircraft prices and transaction dates are reported for 2,086 domestic and 578 international sales.[24] All aircraft delivered to foreign air-carriers and aircraft sold to scrap yards were dropped from the data set. These data were previously used in two earlier works: the aforementioned Smith (2010) and Pulvino (1998).[25]

Additional data is used from another aviation-consulting firm, Back Aviation Solutions. This data set includes aircraft transactions and technical specifications from 1978 through 1991. Transactional information includes order dates, delivery dates and the participants in each transaction. Technical specifications are included. The Back Aviation Solutions transaction and technical specification data set is substantially incomplete for narrow-body aircraft. Data had to be obtained from an alternative source to fill omitted data fields. Fortunately, technical data is available in The International Directory of Civil Aircraft 2003/2004 (Frawley 2003). Much of this combination of data was used by Smith (2010). However, he did not include narrow-body aircraft in his research and consequently did not face incomplete transactional data.

[24] Commercial aircraft sold for military applications – a fairly common practice – are not reported. There should be little demand-side effect from this omission.

[25] Pulvino (1998) studied the effects of capital constraints on used aircraft sales and sale prices. He performs reduced- form regressions in an effort to determine whether prices fall when a firm liquidates aircrafts i.e. Pulvino tests the "market depth" for aircraft.

5.2 Data Summary

Tables 2, 3 and 4 summarize the data. Table 2 shows the raw price data for new and used commercial aircraft.

Table 2

(Price in Millions of 2000 Dollars)

	Observations	
	New	Used
	2736	1871
	Price	
Mean	38.9	16.0
(s.d.)	(22.1)	(13.7)
Median	31.4	10.4
Min	18.4	0.9
Max	161.1	97.5

While not included in my model, the frequent purchasing of multiple aircraft in the same transaction raises the possibility of non-linear pricing in the form of "bulk discounts" in aircraft. Table 3 lists the average price for aircraft sold as singletons versus those sold in larger numbers. Table 3 shows that there is only a 6% price difference between aircraft sold as singletons and those sold in "bulk": up to 29 units. This does not provide evidence of considerable non-linear pricing. Table 11, at the end of the paper, gives details of per-unit prices for specific aircraft. Again, there is no substantive evidence of non-linear pricing. The absence of non-linear pricing is consistent with modeling each air-route as a separate transaction.

Table 3

Price of New Aircraft in Millions of 2000 USD.			
Transactions with only one aircraft		Transactions with more than one aircraft	
N	663	N	530
Mean	42.8	Mean	40.0
(s.d.)	23.6	(s.d.)	23.5
Min	17.3	Min	14.7
Max	157.2	Max	161.1

New and used aircraft are split into four separate nests each for analysis (based on whether they are wide- or narrow-body and are long- or short-range), as delineated earlier in Table 1. Table 4 summarizes the pricing characteristics of the eight aircraft nests.

Table 4 shows the relative prices within the different nests. The left, new aircraft, column shows the average wide-body long-range aircraft, priced at $97.1 million is approximately three times as expensive as either narrow-body aircraft type. The used aircraft prices exhibit a greater relative price difference between wide-body long-run aircraft and narrow-body aircraft. The average used wide-body long-run aircraft is approximately five times as expensive as the average narrow-body aircraft. This difference in relative prices is due to the large stock of older narrow-body aircraft in the market compared to newer wide-body aircraft. For example, the oldest narrow-body aircraft in the market was introduced in 1958. Conversely, the oldest wide-body aircraft was introduced in 1970; therefore, any wide-body aircraft sold from 1978-1991 should be considerably younger, and trade for less of an age discount than the older narrow-body aircraft.

Table 4

Price in Millions of Year 2000 Dollars

New Aircraft			Used Aircraft		
Wide-body Long-range	N	190	Wide-body Long-range	N	70
	Mean	$97.1		Mean	$48.4
	(s.d.)	(30.5)		(s.d.)	(17.1)
	Median	$89.1		Median	$42.0
	Min	$57.8		Min	$23.0
	Max	$161.1		Max	$97.5
Wide-body Short-range	N	252	Wide-body Short-range	N	329
	Mean	$65.3		Mean	$30.5
	(s.d.)	(9.8)		(s.d.)	(13.9)
	Median	$64.0		Median	$28.9
	Min	$45.9		Min	$7.3
	Max	$89.0		Max	$86.7
Narrow Body Long-range	N	1511	Narrow Body Long-range	N	1137
	Mean	$32.4		Mean	$11.7
	(s.d.)	(9.9)		(s.d.)	(8.5)
	Median	$30.0		Median	$9.3
	Min	$18.1		Min	$0.6
	Max	$60.7		Max	$55.0
Narrow Body Short-range	N	783	Narrow Body Short-range	N	335
	Mean	$28.8		Mean	$9.7
	(s.d.)	(5.4)		(s.d.)	(4.9)
	Median	$27.4		Median	$8.8
	Min	$18.5		Min	$2.6
	Max	$47.3		Max	$37.3

Figure 4 at the end of the paper shows the difference between the pre- and post-tax price in year 2000 dollars over time. Consistent with my modeling of the markup equations above, the mean price of aircraft does not fall over time. That is, the marginal cost of production may be expected to fall because of learning-by-doing; however, the transaction price of aircraft is *rising* over time.[26]

Quarterly used aircraft sales are diverse. In the most diverse quarter 93 used aircraft are sold in the market. Considering each aircraft model of the same age as a separate aircraft type reduced the number of different used aircraft types in the same quarter to 36. However, 36 used aircraft types proved too large a number for tractable simulations. Identical used aircraft models sold in a given quarter were averaged by age and price within that quarter. This aggregation reduced the number of used aircraft types in the above example to a manageable 13. For example, 10 used aircraft were sold in the first quarter of

[26] Reduced form estimation, regressing price on passenger capacity, maximum takeoff weight, range, and fuel cost, shows prices go up in all eight cells from 1986 onward. However, the price increase is only statistically significant -- at the 10% level -- in three of the eight cells.

1978. Among the 10 aircraft, there were two Boeing 727-100, one of 12 and the other of 13 years of age. They were sold for $8.48 and $8.53 million respectively. For estimation purposes these two aircraft were considered two identical 12½ year old aircraft sold for $8.50 million dollars. [27]

Finally, as fuel costs likely influence the utility associated with any aircraft purchase, the BLS's Producer Price Index for Fuel Costs is used as a common regressor for all aircraft.

5.3 Taxes

Because of taxation, the two sides of the market face different prices. The agent that ultimately absorbs the subsidy faces the economic incidence, whereas the agent who gets paid the subsidy faces the statutory incidence. The statutory incidence of the tax is gained by the air-carriers. Therefore the air-carrier face the price, $\tilde{P} = P \bullet (1 - s_t)$. The value of the subsidy, s_t, is quite complex and varied historically. From 1978-1981 the effective price to the air-carrier is given by $\tilde{P} = P \cdot (1 - ITC_y) \cdot (1 - MTR_y \frac{D_y(n)}{(1+r)^n})$, where P is the "list price" paid to the manufacturer, ITC_y is the year *y's* investment tax credit, and $D_y(n)$ is the discounted sum of future depreciation benefits. A depreciation rule D can vary by year y and lasts n years where n also can vary by depreciation rule. MTR_y is the marginal tax rate in year y, and r is the interest rate (held constant at 5%) discounted for n years as appropriate.[28] From 1982–1986, the after-tax price formula changes slightly to $\tilde{P} = P \cdot (1 - \frac{ITC_y}{2}) \cdot (1 - MTR_y \frac{D_y(n)}{(1+r)^n})$, to allow half of the ITC-discount of the list price to count as investment for depreciation purposes. From 1986 onward the ITC was zero and falls out of the formulas.

The ITC changed from 7% to 10% in 1981 and was finally removed in 1987. In addition, the depreciation schedule changed from 9 years to 5 years in 1981 and 7 years in 1987. Finally, the marginal tax rate fell from 48% to 46% in 1980 and then to 34% in 1986.[29] Table 5 summarizes the

[27] Owing to the age of used aircraft having a non-linear impact on price, this method may overestimate a used aircraft's price. However, within quarters the mean standard deviation of age for a aircraft model is quite low: 1.2 years.
[28] Leasing contracts between firms effectively allow for the transfer of both depreciation allowances and ITCs. An unprofitable airline with no tax liability would still pay a lower price for an aircraft because the aircraft could be owned by a firm with sufficient tax liability to enjoy the benefits of both the depreciation allowance and the ITC. Many large firms, such as General Electric and Citibank, own, but do not operate, aircraft that are leased to airlines.
[29] Notably, TRA86 removed the ITC retroactively for all capital purchases in 1986. All other tax changes were implemented in 1987.

changes in the tax code from 1978-1991. Some of tax code variation is visible in the new aircraft graphs of Figure 3 at the end of the paper. Figure 3 shows the averaged price before and after taxes in each of the four market segments for both new and used aircraft. Only average prices are presented in the used aircraft graphs, as used aircraft received no favorable tax treatment. In all new aircraft cases, mean prices in Year 2000 dollars are fairly stable with a slight upward trend. Used aircraft prices are also fairly stable across time. Note that the mean post-tax price is *lower* than the pre-tax price because of depreciation allowances and the ITC. Other than a noticeable jump in aircraft prices for new wide-body short-range aircraft, the TRA86 has limited pricing impact that is evident in the raw data. Other exogenous price changes, such as 1981's ERTA, are not apparent.

Table 5

Year	Marginal Tax Rate	ITC	Depreciation Rule	Years Until Full Depreciation
1978	48%	7%	Sum of Years	9
1979-1980	46%	7%	Sum of Years	9
1981	46%	10%	Declining Balance*	5
1982-1985	46%	10%	Declining Balance	5
1986	46%	0%	Declining Balance	5
1987-1991	34%	0%	Declining Balance	7

* Firms were allowed to depreciate from the pre-ITC price.

5.4 Market Size

The 2000 Air Carrier Activity Information System (ACAIS) was used to estimate the number of air-routes.[30] Air-routes are used as the market size, *M*, in this model. The ACAIS is a yearly publication by the Federal Aviation Administration (FAA). Year 2000 data was used as the earliest available data. The ACAIS provides the number of passenger enplanements for all 419 US primary airports. The busiest airport by enplanement was the Hartsfield-Jackson Atlanta International Airport with over 39 million passengers in 2000.

The FAA classifies airports into large, medium, small, and non-hub. While this model allows for air-carriers to select both wide- and narrow-body aircraft for an air-route, *i*, many smaller airports cannot be utilized by wide-body aircraft. To mitigate the possibility of including an inappropriate airport in my air-route market, my final specifications only include large and medium airports; however, smaller airports were included for robustness in some estimations. A large airport is one that services at least 1% of all enplanements. In 2000 there were 32 airports categorized as large. The smallest of the FAA categorized

[30] ACAIS is available online. Retrieved October 20, 2010 from http://www.faa.gov/airports/planning_capacity /passenger_allcargo_stats/passenger/

large airports was Chicago Midway airport with roughly 7 million enplanements. A medium airport is one that enplanes at least ¼% but less than 1% of all enplanements. In 2000, the smallest of the 36 medium airports was Port Columbus with 3.4 million passengers enplaned. The FAA-categorized 75 airports as small, with more than $^{1}/_{20}$% and less that ¼% of all enplanements. The small airport with the lowest enplanement was Long Beach/Daugherty Field with 335,000 per year.

An air-route is a one-way trip from one airport to another airport, so there are *n(n-1)* air-routes, where *n* is the number of airports in a system. There are a total of 68 airports categorized as medium or large; this yields a market size of 4,556. Owing to uncertainty regarding the number of airports which can be utilized by all aircraft in the data set, I conduct estimation for alternative market sizes to demonstrate the robustness of the 68-airport choice.

6. Estimation

Estimation was done in two parts. I estimate demand equations using 2SLS. Cost estimates were then obtained using OLS.

6.1. Demand

I observe all aircraft sales in each quarter, *t*, where *t* runs from 1978:1 through 1991:4. New aircraft of the same model sold in the same quarter are pooled together to form a share of total aircraft sales of type *j* in quarter *t*, such that, $s_{j,t} = \frac{\sum q_j}{M}$ for each quarter. The transaction prices for all aircraft sold in the same quarter, $s_{j,t}$, are averaged together to get a price $p_{j,t}$. Used aircraft of the same model sold in the same quarter are also pooled. In any quarter, all used aircraft of the same model are pooled and their prices and ages are averaged to create an mean price and age for that used aircraft model in that quarter. Once all new and used aircraft sales in each quarter are pooled into shares of identical aircraft models, there are 979 shares across 14 years. The within-group share of an aircraft is also used as a right hand side variable. The within group share for each quarter is $s_{j|g} = \frac{\sum q_j}{Q_g}$, where Q_g is the sum of all aircraft sold in a nest in a quarter.

2SLS estimates of demand parameters are presented in Table 6. The standard errors are parenthetically reported beneath each estimate. These are the White standard errors to control for the likely presence of heteroscedasticity. The estimates are very precise, with all but one estimate statistically significant to the

1% level.

Table 6

Nested-Logit Aircraft Demand Parameter Estimates (N=979)

	(I) M=992	(II) M=20,306	(III) M=4,556	(IIII) OLS
Price (After Tax)	-0.0505	-0.0505	-0.0505	-0.0200
	(0.0107)	(0.0106)	(0.0106)	(0.0025)
Passenger Seats (100s)	2.6223	2.6136	2.6150	2.1408
	(0.3401)	(0.3357)	(0.3364)	(0.3000)
Passenger Seats squared	-0.5161	-0.5149	-0.5151	-0.4199
	(0.0588)	(0.0581)	(0.0582)	(0.0468)
Maximum Takeoff Weight	-2.1075	-2.1009	-2.1020	-2.0350
(Tons of Payload)	(0.4462)	(0.4430)	(0.4435)	(0.3624)
Maximum Takeoff Weight squared	0.7780	0.7767	0.7769	0.6463
	(0.0893)	(0.0884)	(0.0885)	(0.0761)
Range (1000s of km.)	0.4040	0.4056	0.4053	0.3621
	(0.0767)	(0.0758)	(0.0760)	(0.0597)
Range squared	-0.0217	-0.0218	-0.0218	-0.0209
	(0.0037)	(0.0037)	(0.0037)	(0.0030)
Age	-0.0556	-0.0558	-0.0558	-0.0277
	(0.0093)	(0.0093)	(0.0093)	(0.0041)
Fuel Price (PPI)	-0.0041	-0.0035	-0.0036	-0.0020†
	(0.0014)	(0.0014)	(0.0014)	(0.0012)
Trend	0.0302	0.0284	0.0287	0.0201
	(0.0042)	(0.0042)	(0.0042)	(0.0016)
σ	0.7407	0.7420	0.7418	0.5629
	(0.1620)	(0.1606)	(0.1608)	(0.0236)
1st Stage R^2 (Price)††	0.833	0.833	0.833	R^2=0.517
1st Stage *F*-test (Price)	282.05	282.05	282.05	--
1st Stage R^2 (σ)	0.2627	0.2627	0.2627	--
1st Stage *F*-test (σ)	20.15	20.15	20.15	--

Standard errors are reported parenthetically beneath the appropriate parameter estimate.
†, Indicate significance at the 10% level. All other estimates significant at the 1% level

††, Instruments are the BLP instruments: log of average seats of other aircraft in the same group, log of average seats all other aircraft, etc.

Columns I, II, and III present 2SLS estimates using three different market sizes. The market size, which is the number of one-way air-routes, depends on the number of airports included. Column I, M=992, includes only the FAA-rated large airports. Column II, M=20,306, uses all airports rated large, medium, and small by the FAA, while column III uses the 68 airports categorized as large or medium. As can be seen, market size has very little impact on the parameter estimates.[31] As discussed in Section 5.4, using the large and medium sized airports raises the likelihood that the included 68 airports can service any aircraft in the choice set, including wide-body aircraft. I use the 2SLS estimates from column III as the best approximation of aircraft demand. Column IV reports the OLS estimates of the parameters.

The estimates show the expected negative effect of after-tax price on share. The price parameters are well-identified by the many exogenous changes in the tax code. A downward bias in the after-tax price of the OLS estimates is evident when comparing the OLS estimates to the 2SLS estimates. The lower OLS estimate of the average effect α of price on utility can be attributed to positive correlation between price and unobserved quality ξ. The same correlation can be seen for the within-group parameter σ. I used instruments for both price and the within-group share in columns I, II, and III. Following the BLP approach, I use characteristics of other aircraft. Instruments include the log of range, passenger capacity, and maximum takeoff weight, and the squares of the same, for all other aircraft in the same nest as the aircraft with the endogenous price and within–group share. I also used the log of the squares of range, passenger capacity, and maximum takeoff weight for all other manufactured aircraft.[32] These variables should be correlated with the endogenous variables of the subject aircraft but uncorrelated with that aircraft's unobserved quality error term ξ.

For example, the price of a Boeing 737 should be correlated with its unobserved quality "error" ξ. Moreover, Boeing prices the 737 to compete against several similar, perhaps substitute aircraft. The passenger capacity, range, and takeoff weight of a McDonnell Douglas MD-80 should be closely correlated with the price of the 737, as both aircraft were built as close substitutes. However, the descriptive variables of the MD-80, passenger capacity etc, shouldn't be correlated with the unobserved quality "error" of the 737. These instruments achieved an excellent fit for the aircraft price parameter, α, with an R^2 of .83 and a fair fit of the within group share parameter, σ, with an R^2 of .26. The F-statistics of the instruments in both first-stage regressions are quite high.

Passenger seat capacity, maximum takeoff weight, and range, along with the squares of each, are the descriptive characteristics included on the right-hand side for each aircraft. All of these parameters are statistically significant and of the expected sign. The precision of the estimated effect of passenger

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[31] The constant varies with market size. The constants are -7.08, -8.67, and 10.17 for M=992; 4,556; and 20,306 respectively. The constant estimates are the most sensitive estimates to market size; however, they have little economic interpretation.

[32] The log of the range, passenger capacity, and maximum takeoff weight, for all other aircraft were dropped because of collinearity.

capacity indicates that the entrance and exit of aircraft types of similar make with differing passenger capacity was sufficient to identify the importance of this relatively flexible aircraft configuration parameter. Many aircraft models, such as the 767-300, have both regular and extended range configurations. These two models of the 767 are otherwise observationally identical; consequently, the effect of additional range capability on the market share of an aircraft is well identified. The parameter estimates for passenger capacity and range indicate economically intuitive increases in demand resulting from increases in these variables, at a decreasing rate.

Maximum takeoff weight is the gross of cargo and fuselage. I attribute the negative parameter on this variable, which was initially surprising, to fuel inefficiency. The negative impact of heavier, less fuel-efficient aircraft on market share is reasonable after controlling for seating capacity and range.

The parameter estimate for the cost of fuel is well-identified by the fuel-price spike in 1981. This indicates the expected negative effect of high fuel costs in the fuel-intensive air-carrier industry.

Time-trending unobservables might include computerization of scheduling and bookings, technological innovation in airports, etc. The positive time trend indicates that ownership of all aircraft was becoming more profitable.

The value of .74 for the within-group correlation σ shows that aircraft sales are highly correlated within the eight groups delineated in section 4.1. This indicates that aircraft are better substitutes within groups than across groups. The 2SLS estimate is considerably greater than Irwin and Pavcnik's (2004) original estimate of .48 and remarkably similar to Benkard's estimate of .77. Benkard's use of only one "inside" group – new wide-body aircraft – is consistent with a slightly higher within-group parameter. An agent is more likely to substitute to another broadly defined new wide-body aircraft than an outside good. Irwin and Pavcnik's lower estimate might be explained by the inclusion of used aircraft in their outside option. Unlike my model, Irwin and Pavcnik's does not include an option for not purchasing an aircraft.

6.2. Markup Equations

The markup equations are estimated using results from the demand estimation. The price parameter estimate $\hat{\alpha}$, the within-group parameter $\hat{\sigma}$ and the share data are used to compute the markup b over cost:

$$b = \frac{(1-\hat{\sigma})}{\hat{\alpha}(1+\tau_t)[1-\hat{\sigma}\sum_{h\in g_f}\bar{s}_{h|g} - (1-\hat{\sigma})\sum_{h\in g_f} s_h]}$$

Once the markup is differenced from the *pre-tax* price, p_{jt}-b_{jt}, a simple "hedonic" pricing regression can be used. The cost variables are the same as those used in demand estimation; higher-order terms are omitted because of collinearity. This collinearity dramatically reduces the precision of the estimates without changing the R^2.[33] Also, fixed effects are included for each manufacturer, using Boeing as a baseline. The estimates of markup parameters are given in Table 7.

Costs should be interpreted carefully in this model, as noted earlier. A manufacturer's actual marginal cost may be falling with additional units of production; however, as seen in Figure 3, prices are fairly stable. This combination of stable prices and falling marginal cost may be explained by aircraft manufacturers pricing all past, current, and future units based on anticipated marginal cost.

Table 7

Pricing Estimation (N=427)*

Passenger Seats (100s)	9.66
	(1.87)
Maximum Takeoff Weight (Tons of Payload)	14.27
	(2.48)
Range (1000s of km.)	1.05
	(0.30)
Airbus Fixed effect	10.48
	(1.66)
British Aerospace fixed effect	20.62
	(1.05)
Fokker fixed effect	8.76
	(2.21)
Lockheed fixed effect	6.67
	(2.78)
McDonnell Douglas fixed effect	9.46
	(1.23)
Trend	0.61
	(0.03)
Adjusted R^2	0.89

Standard errors are reported parenthetically beneath the appropriate parameter estimate.
*All estimates are statistically significant at the 1% level.

[33] This collinearity was mitigated in the demand side estimation by the inclusion of the additional within-group regressor variable $\bar{s}_{j|g}$.

All parameter are precisely estimated. Moreover, all of the parameters are positive and economically reasonable. They show that aircraft are priced based on capabilities (takeoff weight, range). Also, the fixed effects, which are in comparison with Boeing's fixed effect, are all positive. Boeing's market dominance over the data range might be related to lower costs. The possibly unintuitive parameter is the time trend. One might expect that cost would fall over time as new technological innovations are implemented. One possible explanation for the positive cost trend might be increased safety regulations over time mitigating any cost-saving innovation. The FAA regularly issues airworthiness directives that require all future production of the pertinent aircraft models to incorporate improvements to insure airworthiness. There has also been substantial aircraft noise abatement legislation. By way of comparison, the automotive industry was required to install airbags on all car models by 1989. This regulated increase in manufacturing cost may have negated any cost-saving innovations over time. Both Berry, Levinsohn, Pakes (1995) and Fershtman, et al (1999) estimate a positive cost trend in the automobile industry.

6.3 Demand Elasticities

Findings can be interpreted by computing own and cross price demand elasticities. Each elasticity is calculated using the parameters estimated from the share equations. The own price elasticity is given by

$$\eta_j = \frac{\partial \ln s_j}{\partial p_j} \cdot p_j = \left[1 + \left(\frac{\sigma}{(1-\sigma)} - \frac{\sigma}{(1-\sigma)} \bar{s}_{j|G} \right) - s_j \right] \alpha p_j .$$

The cross-price elasticity between two aircraft in the same group, $j,g \in G$, is given by

$$\eta_{jg} = \frac{\partial \ln s_j}{\partial p_g} \cdot p_g = -\left[\frac{\sigma}{(1-\sigma)} \bar{s}_{g|G} + s_g \right] \alpha p_g .$$

The cross-price elasticity between two aircraft in different groups is given by

$$\eta_{jk} = \frac{\partial \ln s_j}{\partial p_k} \cdot p_k = -\alpha s_k p_k .$$

To calculate numerical estimates of the elasticities, the aircraft shares, s_j, for all aircraft within a nest were averaged over all quarters before TRA86. Then, the quarterly post-tax price, $\tilde{P}_j$, for all aircraft within a nest was averaged over all quarters before TRA86. These averages, one post-tax price and one share per nest, were used to calculate the elasticities presented in the upper portion of Table 8. The process was repeated using the quarterly average prices and shares after TRA86, and the resulting calculations are presented in the lower panel of Table 8. Standard errors for the elasticities were computed using the delta method and are parenthetically reported beneath each elasticity. All calculated elasticities are statistically significant at the 1% level.

Table 8

Elasticities before and after TRA86*

Before TRA86

		New Aircraft				Used Aircraft			
	Own Price	WBLR	WBSR	NBLR	NBSR	WBLR	WBSR	NBLR	NBSR
New Wide-body Long-Range (WBLR)	-10.04 (2.34)	***7.84*** (1.69)	1.84 x10^{-3} (0.39 x10^{-3})	2.41 x10^{-3} (0.51 x10^{-3})	1.06 x10^{-3} (0.22 x10^{-3})	1.37 x10^{-3} (0.29 x10^{-3})	0.92 x10^{-3} (0.19 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	0.25 x10^{-3} (0.05 x10^{-3})
New Wide-body Short-Range (WBSR)	-7.81 (1.67)	1.89 x10^{-3} (0.40 x10^{-3})	***4.24*** (0.91)	2.41 x10^{-3} (0.51 x10^{-3})	1.06 x10^{-3} (0.22 x10^{-3})	1.37 x10^{-3} (0.29 x10^{-3})	0.92 x10^{-3} (0.19 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	0.25 x10^{-3} (0.05 x10^{-3})
New Narrow-body Long-range (NBLR)	-3.94 (0.84)	1.89 x10^{-3} (0.40 x10^{-3})	1.84 x10^{-3} (0.39 x10^{-3})	***1.64*** (0.35)	1.06 x10^{-3} (0.22 x10^{-3})	1.37 x10^{-3} (0.29 x10^{-3})	0.92 x10^{-3} (0.19 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	0.25 x10^{-3} (0.05 x10^{-3})
New Narrow-body Short-range (NBSR)	-2.67 (0.57)	1.89 x10^{-3} (0.40 x10^{-3})	1.84 x10^{-3} (0.39 x10^{-3})	2.41 x10^{-3} (0.51 x10^{-3})	***2.44*** (0.53)	1.37 x10^{-3} (0.29 x10^{-3})	0.92 x10^{-3} (0.19 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	0.25 x10^{-3} (0.05 x10^{-3})
Used Wide-body Long-Range (WBLR)	-2.08 (0.44)	1.89 x10^{-3} (0.40 x10^{-3})	1.84 x10^{-3} (0.39 x10^{-3})	2.41 x10^{-3} (0.51 x10^{-3})	1.06 x10^{-3} (0.22 x10^{-3})	***5.98*** (1.29)	0.92 x10^{-3} (0.19 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	0.25 x10^{-3} (0.05 x10^{-3})
Used Wide-body Short-Range (WBSR)	-4.58 (0.98)	1.89 x10^{-3} (0.40 x10^{-3})	1.84 x10^{-3} (0.39 x10^{-3})	2.41 x10^{-3} (0.51 x10^{-3})	1.06 x10^{-3} (0.22 x10^{-3})	1.37 x10^{-3} (0.29 x10^{-3})	***1.96*** (0.42)	0.40 x10^{-3} (0.08 x10^{-3})	0.25 x10^{-3} (0.05 x10^{-3})
Used Narrow-body Long-range (NBLR)	-1.64 (0.35)	1.89 x10^{-3} (0.40 x10^{-3})	1.84 x10^{-3} (0.39 x10^{-3})	2.41 x10^{-3} (0.51 x10^{-3})	1.06 x10^{-3} (0.22 x10^{-3})	1.37 x10^{-3} (0.29 x10^{-3})	0.92 x10^{-3} (0.19 x10^{-3})	***0.34*** (0.07)	0.25 x10^{-3} (0.05 x10^{-3})
Used Narrow-body Short-range (NBSR)	-1.05 (0.23)	1.89 x10^{-3} (0.40 x10^{-3})	1.84 x10^{-3} (0.39 x10^{-3})	2.41 x10^{-3} (0.51 x10^{-3})	1.06 x10^{-3} (0.22 x10^{-3})	1.37 x10^{-3} (0.29 x10^{-3})	0.92 x10^{-3} (0.19 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	***0.62*** (0.13)

After TRA86

		New Aircraft				Used Aircraft			
	Own Price	WBLR	WBSR	NBLR	NBSR	WBLR	WBSR	NBLR	NBSR
New Wide-body Long-Range (WBLR)	-12.00 (2.56)	***6.63*** (1.43)	2.67 x10^{-3} (0.56 x10^{-3})	4.08 x10^{-3} (0.86 x10^{-3})	3.34 x10^{-3} (0.70 x10^{-3})	1.09 x10^{-3} (0.23 x10^{-3})	0.85 x10^{-3} (0.18 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	0.49 x10^{-3} (0.10 x10^{-3})
New Wide-body Short-Range (WBSR)	-7.53 (1.60)	3.21 x10^{-3} (0.67 x10^{-3})	***7.13*** (1.54)	4.08 x10^{-3} (0.86 x10^{-3})	3.34 x10^{-3} (0.70 x10^{-3})	1.09 x10^{-3} (0.23 x10^{-3})	0.85 x10^{-3} (0.18 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	0.49 x10^{-3} (0.10 x10^{-3})
New Narrow-body Long-range (NBLR)	-5.59 (1.19)	3.21 x10^{-3} (0.67 x10^{-3})	2.67 x10^{-3} (0.56 x10^{-3})	***1.44*** (0.31)	3.34 x10^{-3} (0.70 x10^{-3})	1.09 x10^{-3} (0.23 x10^{-3})	0.85 x10^{-3} (0.18 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	0.49 x10^{-3} (0.10 x10^{-3})
New Narrow-body Short-range (NBSR)	-3.68 (0.79)	3.21 x10^{-3} (0.67 x10^{-3})	2.67 x10^{-3} (0.56 x10^{-3})	4.08 x10^{-3} (0.86 x10^{-3})	***1.72*** (0.37)	1.09 x10^{-3} (0.23 x10^{-3})	0.85 x10^{-3} (0.18 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	0.49 x10^{-3} (0.10 x10^{-3})
Used Wide-body Long-Range (WBLR)	-5.29 (1.13)	3.21 x10^{-3} (0.67 x10^{-3})	2.67 x10^{-3} (0.56 x10^{-3})	4.08 x10^{-3} (0.86 x10^{-3})	3.34 x10^{-3} (0.70 x10^{-3})	***4.36*** (0.94)	0.85 x10^{-3} (0.18 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	0.49 x10^{-3} (0.10 x10^{-3})
Used Wide-body Short-Range (WBSR)	-4.64 (0.99)	3.21 x10^{-3} (0.67 x10^{-3})	2.67 x10^{-3} (0.56 x10^{-3})	4.08 x10^{-3} (0.86 x10^{-3})	3.34 x10^{-3} (0.70 x10^{-3})	1.09 x10^{-3} (0.23 x10^{-3}))	***1.42*** (0.31)	0.40 x10^{-3} (0.08 x10^{-3})	0.49 x10^{-3} (0.10 x10^{-3})
Used Narrow-body Long-range (NBLR)	-2.40 (0.51)	3.21 x10^{-3} (0.67 x10^{-3})	2.67 x10^{-3} (0.56 x10^{-3})	4.08 x10^{-3} (0.86 x10^{-3})	3.34 x10^{-3} (0.70 x10^{-3})	1.09 x10^{-3} (0.23 x10^{-3})	0.85 x10^{-3} (0.18 x10^{-3})	***0.33*** (0.07)	0.49 x10^{-3} (0.10 x10^{-3})
Used Narrow-body Short-range (NBSR)	-1.40 (0.30)	3.21 x10^{-3} (0.67 x10^{-3})	2.67 x10^{-3} (0.56 x10^{-3})	4.08 x10^{-3} (0.86 x10^{-3})	3.34 x10^{-3} (0.70 x10^{-3})	1.09 x10^{-3} (0.23 x10^{-3})	0.85 x10^{-3} (0.18 x10^{-3})	0.40 x10^{-3} (0.08 x10^{-3})	***0.77*** (0.17)

* All elasticities are significant at the 1% level

The elasticities reported in Table 8 are intuitive and appealing. Each elasticity gives the percent change in quantity for a 1% increase in price. The first column gives the own-price demand elasticity. The numbers in bold italics are the cross-price elasticity for other aircraft within the same nest. The cross price elasticities are interpreted as the percentage increase in demand of the column good for a 1% increase in the price of the row good. All of the out-of-group cross price elasticities are extremely small. The size of the out-of-group cross price elasticities is consistent with the small overall share of total sales enjoyed by any aircraft type. Identical elasticities within the same column is an artifact of the logit model assigning share changes proportional to the incumbent share of a nest. All elasticities have the appropriate sign and magnitude, with the own-price reducing demand and cross-price raising other aircraft demand. As seen in the first column, most own-price elasticities increased in magnitude after TRA86.

This indication that aircraft are becoming more sensitive to price changes has two probable causes. First, additional aircraft are competing in all market segments. And second, all of the aircraft demand curves are getting “flatter” after the removal of an *ad valorem* subsidy. This increase in elasticity can also be seen in Irwin and Pavcnik (2004). Interestingly, the elasticity for wide-body short-range aircraft goes down slightly after the ITC was removed. This may be attributable to the introduction of more capable short-range wide-body aircraft. As the own-price elasticity goes down, the within-group cross price elasticity goes up

All of the used aircraft models show an increase in own-price elasticity after 1986. As used aircraft are unaffected by the tax laws, this increase in elasticity is likely attributable to the increased numbers of used aircraft available as time progresses.

As aircraft with reduced range and passenger seat capacity are less sensitive to price changes, they have a lower own-price elasticity. This indicates that larger longer-range aircraft could be effectively replaced by narrow-body aircraft.

7. Simulation

7.1 Methodology of Simulation

The estimated demand and markup parameters from column III in Table 6 and from Table 7, respectively, are used as in simulations to calculate goodness-of-fit and to evaluate counterfactual policies. I simultaneously solve a number of non-linear share and markup equations to simulate the market equilibrium. I use the simulated market to show how well the market-clearing prices and shares predicted by the model match the observed data and how they would have behaved under other circumstances.

The number of aircraft available in any quarter changes through the span of my data from 1978 through 1991. Moreover, the historic year-to-year variation in the availability of used aircraft creates considerable ambiguity. In any quarter the transaction price and number of used aircraft sold is observed. However, the actual stock of used aircraft that could come to market is unknown. A slight change in the market price might induce many potential sellers to change their decisions to sell an aircraft: a higher price would likely lead to a higher stock of used aircraft and a lower price would lead to a lower stock. The problem is further complicated by the nature of simulations. A simulated used aircraft price might vary from its historical value as an artifact of the model -- no structural model will fit the data perfectly -- or it might vary from its historical value endogenously because of model counterfactuals. In the case of counterfactual simulations, the stock of used aircraft becomes quite significant. For example, *a priori*, one might speculate a significant impact on the sale of used aircraft when the ITC is removed. This problem is addressed by running multiple simulations under different assumptions about the supply elasticity of used aircraft to establish bounds on the behavior of the used aircraft market.

In each simulation, one share, or demand, equation is created for each aircraft, *j*, in each quarter. The model's demand in the simulations is given as

$$\ln s_j - \ln s_0 = x_j \hat{\beta} + \hat{\alpha}\tilde{p}_j + \hat{\sigma} \ln \bar{s}_{j|g} ,$$

for each aircraft *j*.[34] In this share equation, the theoretical preference parameters β for aircraft characteristics, the effect α of after-tax price on demand, and the within-group preference σ are replaced by their respective estimates.

Historically, aircraft were not sold in a given quarter because of a lack of demand for a particular aircraft, or, more frequently, for a particular aircraft configuration. The lack of sales in a particular quarter are properly categorized as corner solutions. A quick perusal of the demand curve,

[34] The demand equation for a used aircraft is essentially identical. However, there is no difference between the price of used aircraft and the post-tax price of a used aircraft: $\tilde{p}_j = p_j$

$$s_j(\delta(p_j),\sigma) = \frac{e^{\delta(p_j)_j / (1-\sigma)}}{D_g} \cdot \frac{D_g^{(1-\sigma)}}{\sum_{g=0}^{4} D_g^{(1-\sigma)}}, \qquad D_g \equiv \sum_{k \in g} e^{\delta_k / (1-\sigma)} ,$$

shows the well known quandary that it is impossible for a share to be zero. Any aircraft included in the market simulation will require a positive share. To circumvent the problem of simulating aircraft that were historic corner solutions into small positive shares, only aircraft models that were actually sold in a particular quarter are included in a simulation.

One pricing, or markup, equation is generated for each aircraft in each quarter. Analogous with demand simulation, the estimates from Tables 5 and 6 are used in the markup equations. The estimates for the theoretical cost parameters γ on aircraft characteristics, the effect of price on demand, α, and the within-group preference σ are all used. It is the nature of the markup equations that manufacturers take into consideration their market power, which is dependent on α and σ. Each aircraft, j, has a separate pricing equation

$$p_{jt} = \frac{\tilde{p}_{jt}}{(1+\tau_t)} = w_j\hat{\gamma} - \frac{(1-\hat{\sigma})}{\hat{\alpha}(1+\tau_t)[1-\hat{\sigma}\sum_{h \in g_f} \bar{s}_{h|g} - (1-\hat{\sigma})\sum_{h \in g_f} s_h]}.$$ [35]

Technically, each simulation involves solving a set of nonlinear equations without error terms.[36] The number of equations ranges from 18 equations -- 9 aircrafts' demand and supply equations -- to 56 equations for 28 aircraft. This number, from 18 to 56, depends on the number of aircraft historically traded in a particular quarter. Simulations are performed for multiple scenarios under both the historic and counterfactual equilibrium.

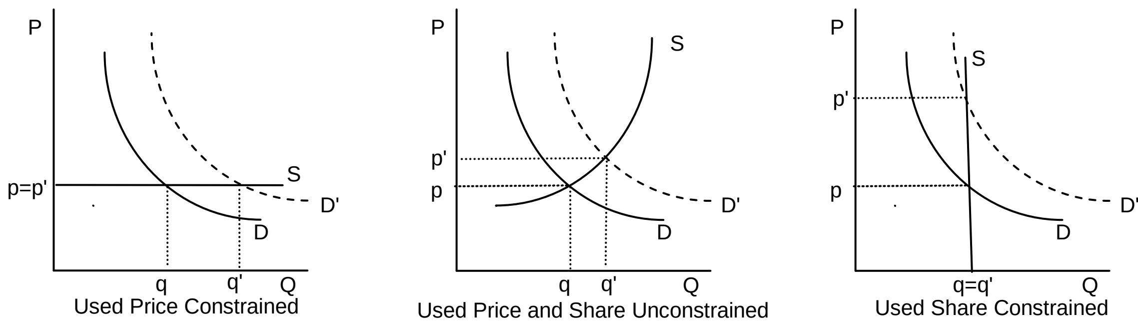
The three scenarios for simulated equilibria are represented in Figure 4 for a hypothetical increase in demand. In the first, leftmost, *Used Price Constrained* scenario, the price of a used aircraft is fixed and the quantity of used aircraft is allowed to vary freely. This is associated with a constant supply of used aircraft being exchanged at their marginal cost. In the middle *Used Price and Share Unconstrained* scenario, the equilibrium allows both price and quantity to vary freely for used aircraft. Under this scenario, used aircraft are allowed to enter the market as the price increases. I assume that sellers have a stock of used aircraft and willingness to sell aircraft sufficient to fill any increases in demand. In the right *Used Share Constrained* scenario, the quantity of the used aircraft is fixed and the price is allowed to respond to changes in demand. In all scenarios, the prices and quantities for *new* aircraft vary freely using Bertrand competition.

[35] See footnote 37 for discussion of used markup equations.
[36] The systems of equations were solved using software I wrote in MATLAB.

The fixed, marginal cost-type, pricing scenario is an equilibrium extreme in which a large (infinite) stock of a used aircraft model is available at its marginal cost. The fixed stock -- vertical supply -- scenario allows for a "fixed quantity" extreme. Neither the fixed price nor fixed supply extremes are likely equilibria for the used aircraft market; however, collectively, they offer firm bounds on the behavior of the market.[37]

Figure 4

Three used aircraft market scenarios



Simulation of the model finds the set of prices and shares that clear the market given the parameter estimates, the constraints on used price and quantity, when imposed, and the exogenous ad valorem subsidy τ.

7.2 Simulations

Figure 5 at the end of the paper has three different panels. The top panel is the simulation conducted with *Used Price and Share Unconstrained*. The middle and bottom panels reflect the simulations conducted under the two constrained scenarios, with an inelastic supply of used aircraft imposed in the middle panel and an elastic supply imposed in the bottom panel. Ostensibly, the simulated results in the top two panels (unconstrained and quantity constrained used aircraft scenarios) appear to track the historical data. The correlation is especially good from 1978 through 1986. After 1986, the simulations still track the historical data in many areas; however, much of the fluctuation in the historical data appears amplified in the simulations. This divergence between the historical and model-generated simulations may be attributable to the larger number of aircraft types being exchanged after 1986. Specifically, there

[37] There is no markup equation for used aircraft under the constant marginal cost equilibrium or the fixed quantity equilibrium. Figure 4's middle equilibrium, in which quantity and price are allowed to naturally equilibrate, is modeled as a heterogeneous Bertrand pricing game. It is represented with a supply and demand model for simplicity.

are an average of 14 types of aircraft -- or 28 simultaneous equations to be solved -- in the simulations before 1986 and 21 types of aircraft -- for 42 simultaneously solved equations -- after 1986. Moreover, the aircraft types are more diverse since 1986.

The bottom panel of figure 5 shows the simulations under the *Used Price Constrained* scenario, assuming perfectly elastic used aircraft supply. The poor performance of the *Used Price Constrained* simulations can be attributed to the nature of the price constraint. Any new aircraft price which is simulated as being above a substitute used aircraft price will drive demand into the marginal cost-priced used aircraft. The large spikes in aircraft purchases, such as in the fourth quarter of 1984, reflect customers purchasing large numbers of used aircraft at a fixed price. In the simulation for the fourth quarter of 1984, customers purchased over 700 copies each of a used 747-100, a used 747-200, and a used DC-8. That is, the poor fit of the *Used Price Constrained* simulations reflects the unrealistic constraint.

8. Counterfactual Simulations

In this section, I perform counterfactual simulations using all three scenarios about used aircraft supply. A counterfactual simulation imposes exogenous changes on the market. The share, markup equations, and tax policies are adjusted to reflect a market state that did not exist over the within-sample estimation: a change which is *counter-factual*. Once the appropriate exogenous changes are made, the models are simulated and a new set of equilibrium prices and shares reflect policy changes in the aircraft market.

The simulation results are broken into two different sections. Section 8.1 covers the historic time period from 1978-1985 when the ITC was in effect. In Section 8.1 the counterfactual will remove the historic ITC thereby isolating the effect of the ITC on aircraft demand. Section 8.2 covers the historic years 1986-1991 when there was no ITC. This section will show the counterfactual impact of a hypothetical ITC on aircraft demand. Section 8.3 discusses the welfare implication of the ITC counterfactuals.

In Section 8.2 I find that applying a hypothetical ITC from 1986-1991 had a positive impact on aircraft demand. Producers and customers split the tax credit in such a way that more new aircraft are purchased after the ITC is introduced. The positive impact on aircraft demand is reflected in sections 8.3's finding that mean quarterly consumer surplus increased by a modest .8% from a net 5.3% ITC.

The results in Section 8.1 are complex. I find that removing the historic ITC from 1978-1985 has a convoluted impact on aircraft demand. From 1978-1985 some manufacturers of new aircraft possessed considerable market power in the narrow-body long- and short-range nests. The incumbent manufacturers were able to exploit their market power to manipulate the customers' demand curves. Manufacturers possessed multi-nest production sets and were able to over-shift the ITC -- raise the price by more than the tax credit. Any customer priced out of the market segment in which the manufacturer enjoyed monopoly-like power would enter another market segment in which that same manufacturer had other products to offer. Again, these complex findings are reflected in the welfare ramifications of the ITC removal. Specifically, I find a meager mean quarterly consumer surplus decrease of .24% for the removal of an average net ITC of 6.9%.

8.1 Removing the ITC

The ITC was utilized from 1978 until 1985. The first counterfactual simulation measures hypothetical prices and quantities of new and used aircraft *without* the ITC. [38]

Table 9 shows the counterfactual change in the pre-tax price from removing the ITC. Table 9 shows the pre-tax price would decrease after the removal of the ITC. When the ITC was in effect firms could charge a higher pre-tax price knowing that customers would be able to claim the ITC. With the elevated prices, firms would "split" the ITC with the customers. When the ITC is removed, firms react by lowering their prices, knowing that the customers no longer get the tax credit.

The *net* ITC was 7.5% from 1978 until 1981, 11.1% in 1981, and 5.3% thereafter.[39] This net ITC corresponds to a *gross* ITC of 7% until 1981 and 10% thereafter. The differences between gross and net ITC come from other changes in tax laws. Table 9 shows that the pre-tax price of the expensive wide-body aircraft would have *deceased* relatively little -- between 2% and 2.5% -- if the ITC were removed. However, the prices of the narrow-body aircraft would have fallen between 6% and 6.5%, with one cell, the narrow-body short-range cell in the *Used Prices Constrained* scenario, showing a decrease of 7.5%.

The price changes from Table 9 are all lower than the net ITC. This suggests that the final price to the consumer would have increased after the ITC was removed and the total demand would have decreased. The three panels of Figure 6, at the end of the paper, represent the three used-aircraft scenarios discussed

[38] The ITC was removed by TRA86 which became effective in 1987; however, the ITC specifically was retroactively removed and could not be claimed for goods purchased in 1986. In this counterfactual I model the ITC as not being utilized in 1986.

[39] The total tax treatment includes depreciation allowances. In some years, the ITC was based on the pre-depreciation base and in other cases post depreciation prices. See Section 5.2.

in Section 7.2. This simulation supports the theoretical finding that removing the ITC makes the purchase of aircraft less attractive.

Table 9

Average Percent Price Change from Removing ITC (1978-1985)

	Used Prices and Shares Unconstrained	Used Shares Constrained	Used Prices Constrained
Wide-body Long-range	-2.34%	-2.33%	-2.34%
Wide-body Short-range	-2.49%	-2.52%	-2.09%
Narrow-body Long-range	-6.43%	-6.34%	-6.07%
Narrow-body Short-range	-6.40%	-6.44%	-7.50%

The top panel of Figure 6 shows the *Used Price and Share Unconstrained* scenario. There is a considerable, yet inconsistent, negative impact on the overall sale of commercial aircraft when the ITC is removed. ITC removal has a negative impact in 29 of the 32 quarters in the graph. Specifically, the top panel of Figure 6 shows that, if the ITC were *removed*, overall aircraft sales would decrease by .97% on average.

The middle panel of Figure 6 shows the results of *Used Share Constrained* simulation in which the shares of used aircraft were held constant. The middle panel of Figure 6 shows a more noisy impact of ITC removal. There is a quarterly average percentage decrease from removing the ITC of .67%. There are 22 quarters simulated as having a negative impact and 10 quarters indicating a positive impact on the number of aircraft sold.

The bottom *Used Price Constrained* panel of Figure 6 is quite "noisy" when compared to the middle and upper panel. As noted earlier, this scenario overly volatile used aircraft sales. On average in the small counterfactual simulation, there is a small decease in the total aircraft sales of .19%. There are 21 quarters in which there is a percentage decrease in sales and 11 quarters in which there is a percentage increase. This result can be attributed to the constraint's interaction with the model. The price of new aircraft increase after the ITC is removed and the used prices are held constant. Customers shift into the less expensive used aircraft market and the used prices are constrained from reacting to the increase in demand. This causes an overwhelming increase in the number of used aircraft sales. The used aircraft price constraint caused unreasonable simulation results.

Table 9 and Figure 6 offer a broad summery of the historical effect of the ITC. A detailed examination of prices and quantity changes reveals a more complex equilibrium. Figure 7 shows the counterfactual percent changes in the price of aircraft from ITC removed.[40] The ITC varied between a 5.3-11.1% tax credit. Consequently, a firm which offers its aircraft at a percentage price markup *less* than the ITC's percentage discount is sharing part of the ITC with the buyer. At times, the markup for narrow-body aircraft is *higher* than the percentage of the ITC. This means that buyers paid a higher price for aircraft after they claimed the ITC discount than they would have had the ITC not been in place: the ITC subsidy acted as a net *tax*.

The detailed impact of these price changes can be seen on in Figure 8. Figure 8 shows the simulated aggregate number, from 1978 - 1985, of aircraft sold under the *Used Price and Share Unconstrained* scenario as well and the resulting counterfactual of removing the ITC.[41] The counterfactual predicted a small, net one-aircraft, change on the number of used aircraft sold. The simulation indicates that a total of 15 new aircraft sales can be directly attributed to the ITC from 1978 through 1985. Note the counterintuitive result that the number of new narrow-body long-range aircraft sold actually would have *increased* if the ITC were removed. This increase is consistent with the final price of these aircraft being higher because of the ITC. The overall quantity of new aircraft increases by 15 units due to the ITC in part because some buyers switch from their desired narrow-body long-range aircraft into another aircraft group. The small, two aircraft, increase of new narrow-body short-range aircraft sales reflects the same price-increasing impact of the ITC.

Figure 9 shows the *Used Share Constrained* scenario in which the number of used aircraft sold is fixed to the historic quantity in both the initial simulation and the counterfactual simulation.[42] Figure 9 versus Figure 8 shows that historic used aircraft sales were greater than the number simulated when the share and price are allowed to vary under the *Used Price and Share Unconstrained* simulations. The ITC has little impact on overall aircraft sales. A total of 13 new sales are attributable to the ITC. Figure 9 shows the same counterintuitive results where narrow-body long-range sales were depressed by the ITC. Also, there is no change in quantity of narrow-body short range aircraft.

[40] Only those quarters in which at least one unit of each nest were sold are included in Figures 7.

[41] The numbers in Figure 8 were generated by multiplying the simulated share by the market size, $M \cdot \hat{s}_{j,t}$ and rounding the number to an integer.

[42] Numerical *Used Price Constrained* results are presented in Figure 10 at the end of the paper. Figure 10 shows a massive and unreasonable demand for used aircraft. Figure 10 indicates that a simulated number of 2,339 used wide-body aircraft were sold: larger than the accumulated total number of wide-body long-range jets built through 1985. As discussed above, the result is an artifact of horizontal supply curve associated with the used price constraint scenario.

Figure7[43]

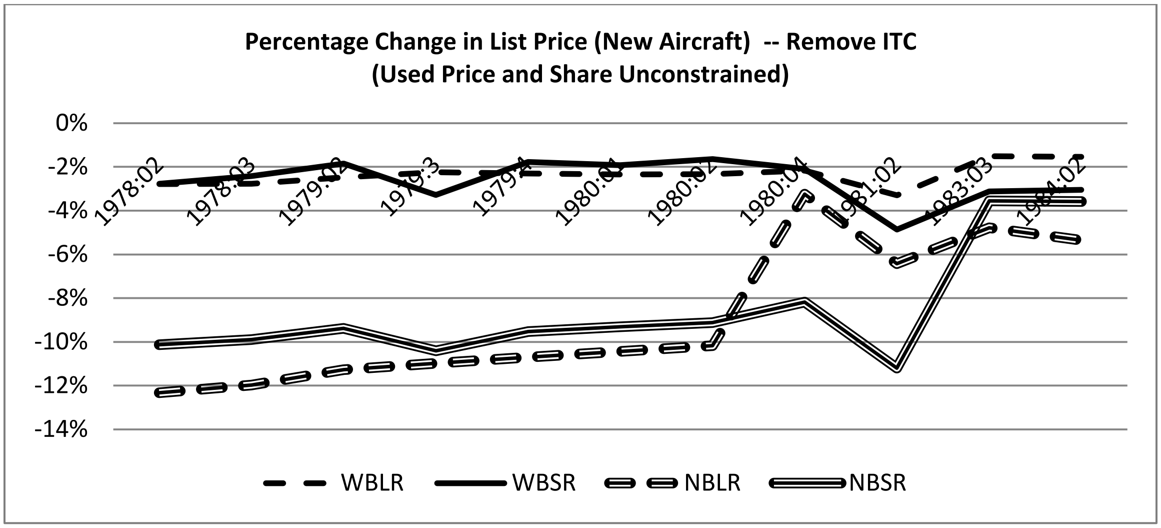
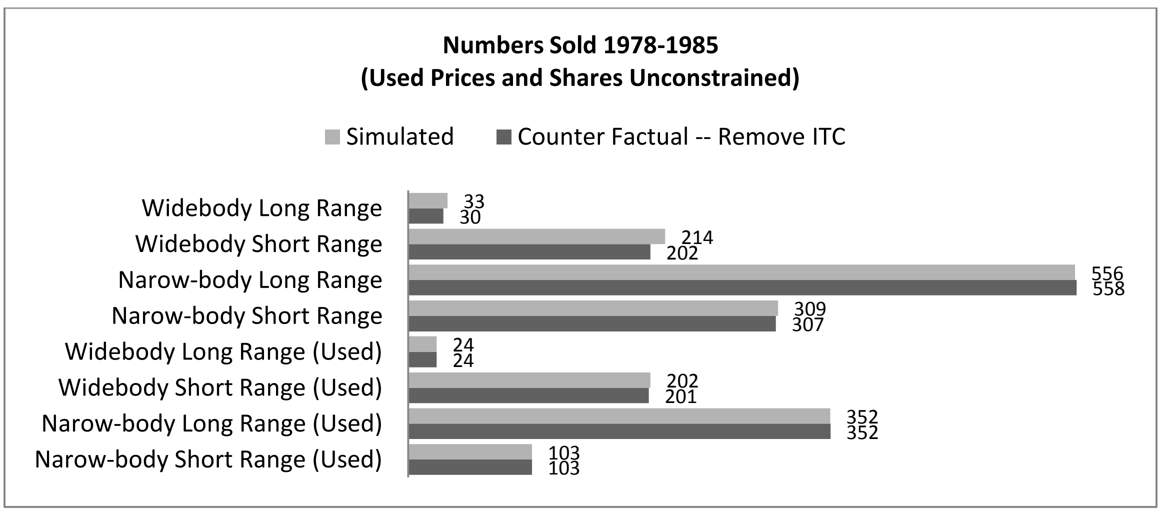


Figure 8



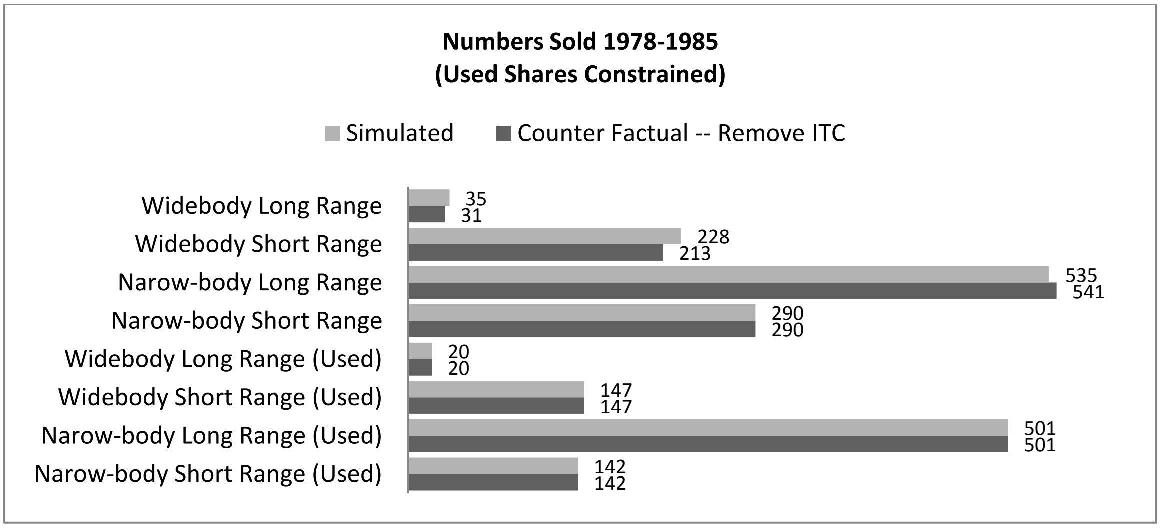
The remarkable narrow-body price and quantity results in Figures 7, 8, and 9 are attributable to market power in the narrow-body aircraft market from 1978-1985. A combination of circumstances allowed the narrow-body manufacturers to exploit their market position. The market power is best understood through the model. The optimal pricing equation for each aircraft under Bertrand pricing competition is given by

$$p_{jt} = w_j \gamma + b_j \text{, where}$$

[43] The percentage change in price simulation results under the *Used Share Constrained* and *Used Price Constrained* scenarios are very similar; they are presented in Figure 7(b) at the end of the paper for completeness.

$$b_j = \frac{(1-\sigma)}{|\alpha|(1-sub_t)[1-\sigma\sum_{h\in g_f}\bar{s}_{h|g} - (1-\sigma)\sum_{h\in g_f} s_h]}.$$

Figure 9



A firm's optimal aircraft price depends on the aircraft's marginal cost, $w_j\gamma$, and the markup above marginal cost b_j. The markup is a function of the subsidy in quarter t, sub_t the price parameter, α, the within-group parameter, σ, the within-group share, $s_{j|g}$, the share, s_j, and the set of aircraft that firm f produces in aircraft j's group, g_f.

The markup, b, increases at an increasing rate in the subsidy:

$$\frac{\partial b}{\partial sub_t} = \frac{(1-\sigma)}{|\alpha|(1-sub_t)^2[1-\sigma\sum_{h\in g_f}\bar{s}_{h|g} - (1-\sigma)\sum_{h\in g_f} s_h]} > 0$$

$$\frac{\partial^2 b}{\partial sub_t^2} = \frac{2(1-\sigma)}{|\alpha|(1-sub_t)^3[1-\sigma\sum_{h\in g_f}\bar{s}_{h|g} - (1-\sigma)\sum_{h\in g_f} s_h]} > 0.$$

A smaller denominator in b creates a larger markup. A firm's market power is the sum of its shares within a group, $s_j \in g_f$,and the sum of its shares conditional on that group being selected $s_{j|g} \in g_f$.

$$Market\ Power = \sigma\sum_{h\in g_f}\bar{s}_{h|g} - (1-\sigma)\sum_{h\in g_f} s_h.$$

The market share, s_j, will of course go down for any increase in price, $\frac{\partial s_j}{\partial p_j} < 0$; however, the within-group share, $s_{j|g}$, will stay constant as price increases if the firm is the only manufacturer in the group. Therefore, if a firm's within-group share, $\sum_{h \in g_f} \bar{s}_{h|g}$, sums to one(1) in *Market Power* it can raise its markup considerably with the subsidy.

Firms simultaneously choose a set of optimal prices for all of their aircraft. Firms that produce in multiple groups -- wide-body long-range, narrow-body long-range, etc -- can significantly raise the price for an aircraft in a group where it has high *Market Power*, while simultaneously playing a Bertrand pricing game in other groups. As a firm loses share in one group from aggressively raising its price, $\frac{\partial s_j}{\partial p_j} < 0$, it can capture some of the lost demand in another substitute group.

Consider an aircraft *j*. If aircraft *j* is the only aircraft in the group, $s_{j|g}$=1, the firm will raises the price with the subsidy to exploit aircraft *j's* within-group share advantage. The overall share of aircraft *j*, s_j, will go down. If aircraft *j* is relatively inelastic, as narrow-body aircraft are, the increase in price will be greater than for more elastic wide-body aircraft. Some of the customers that no longer purchase *j*, will opt for an (imperfect) substitute aircraft *k*. If aircraft *k* is also manufactured by the same firm, then that firm will be willing to raise the price of aircraft *j* even more. Moreover, if σ is greater than ½ -- σ =.74 for the aircraft industry -- the firm weights the sum of its conditional within-group share, $\sum_{h \in g_f} \bar{s}_{h|g}$, greater than the sum of all of its shares, within the group $\sum_{h \in g_f} s_h$.

In the data set, Boeing enjoyed the abovementioned market power from 1978-1982. Boeing was the only manufacturer of narrow-body long-range aircraft until 1981 and Boeing manufactured aircraft in other groups: wide-body long-range, etc. Boeing continued to dominate the market segment after 1981 with an average within-group share of .81 through 1985; nevertheless, the loss of monopoly power is evident in Figure 7. The narrow-body long-range markup is shown to be over 10% -- more than the ITC -- until McDonnell Douglas introduces the long range MD-80's in 1981. After 1981, the markup fell to a moderate 6%.

McDonnell Douglas enjoyed the same within-group market power in the narrow-body short-range group until the British Aerospace BEA-146 entered the market in 1983. The exploitation of the market power is clear in Figure 7 until McDonnell Douglas lost its monopoly. The spike in narrow-body aircraft markup -- as reflected in the downward bend in the percent decrease in price from ITC removal in Figure 7 -- in 1981 perfectly corresponds to the one year in which the ITC was 11.1%.[44]

8.2 Adding the ITC

The second set of counterfactual simulations imposes an ITC on the market. This counterfactual test shows what would happen to new and used aircraft prices and quantities if the historic ITC was provided for commercial aircraft after 1985. Tax policies were stable from 1986 through 1991, and I introduce a reproduction of the historic 1985 ITC -- *net* 5.3% and gross 10% tax credit -- as the counterfactual ITC.

Table 10 shows the percentage change in simulated pre-tax prices with a counterfactual ITC. As expected, the pre-tax price would increase with the ITC. As firms charge a higher pre-tax price knowing that customers will be able to claim the ITC. The elevated prices show that firms and customers "split" the ITC. Table 10 shows customers usually keep more than half of the ITC's subsidy.[45] Figure 11 shows a detailed look at price changes from the new and used price unconstrained scenario: first column of Table 10. Figure 11 tracks the percent changes in pre-tax prices for all four groups. The price markups are quite stable across time and show none of the strong trending when compared to Figure 7.

Table 10

Average Percent Price Change from Adding ITC (1986-1991)

	Used Prices and Shares Unconstrained	Used Shares Constrained	Used Prices Constrained
Wide-body Long-range	1.24%	1.20%	1.45%
Wide-body Short-range	1.51%	1.69%	1.24%
Narrow-body Long-range	2.65%	2.42%	2.59%
Narrow-body Short-range	2.47%	2.28%	1.83%

Table 10 shows that customers' net prices decrease because of the added ITC. Theory suggests that overall sales of aircraft should increase as all new prices are lower because of the ITC. Figure 12, in the back of the paper, presents the results of adding the ITC on the sale of new and used aircraft. The top panel shows the simulated results of the *Used Price and Share Unconstrained* simulation. The middle and bottom panels show the simulations under the *Used Shares Constrained* and *Used Prices Constrained* scenarios respectively.

[44] The net ITC was 7.5% until 1981, 11.1% in 1981, and 5.3% thereafter.
[45] An increase of 2.65% would show that customers and manufacturers are evenly splitting the ITC's subsidy.

The top panel of Figure 12 shows a consistent increase in the overall quantity of new and used aircraft sold. The mean quarterly increase is 3.15%; Figure 13 aggregates the total number of aircraft sold from 1986 through 1991.

Figure 11

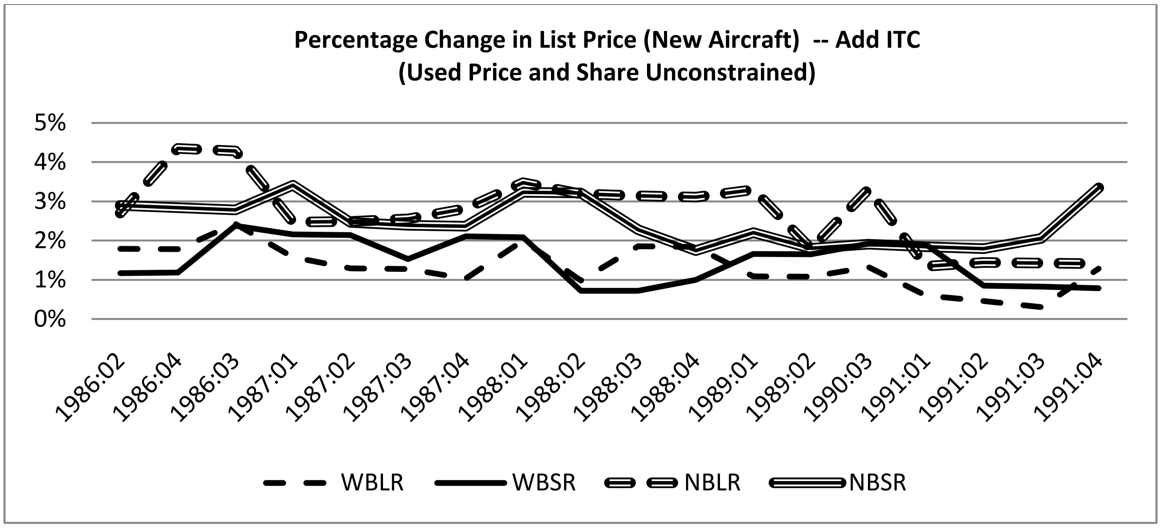
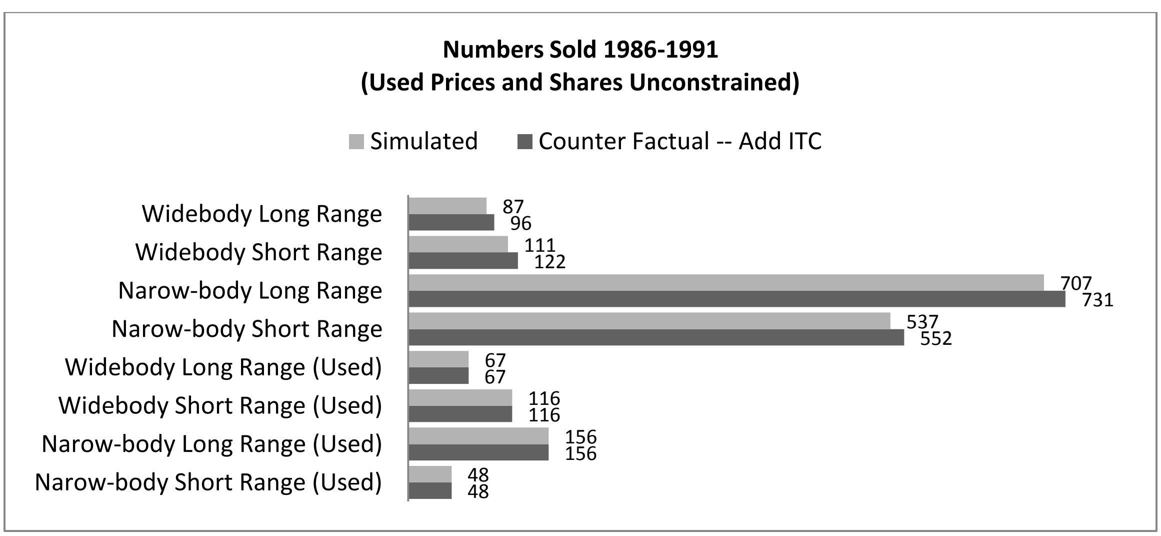


Figure 13 shows a increase of 59 aircraft sales directly attributable to a hypothetical ITC. The addition of an ITC has no impact on the sale of used aircraft. Changes are consistent with the interaction of price changes and elasticities as found in Tables 10 and 8 respectively. Customers keep as least half of the ITC for all aircraft types. The results in Figure 13 offer support for the effectiveness of the ITC as an investing incentive tool. It shows an increase of approximately 3% in new aircraft sales by imposing a *net* 5.3% ITC.

Figure 13

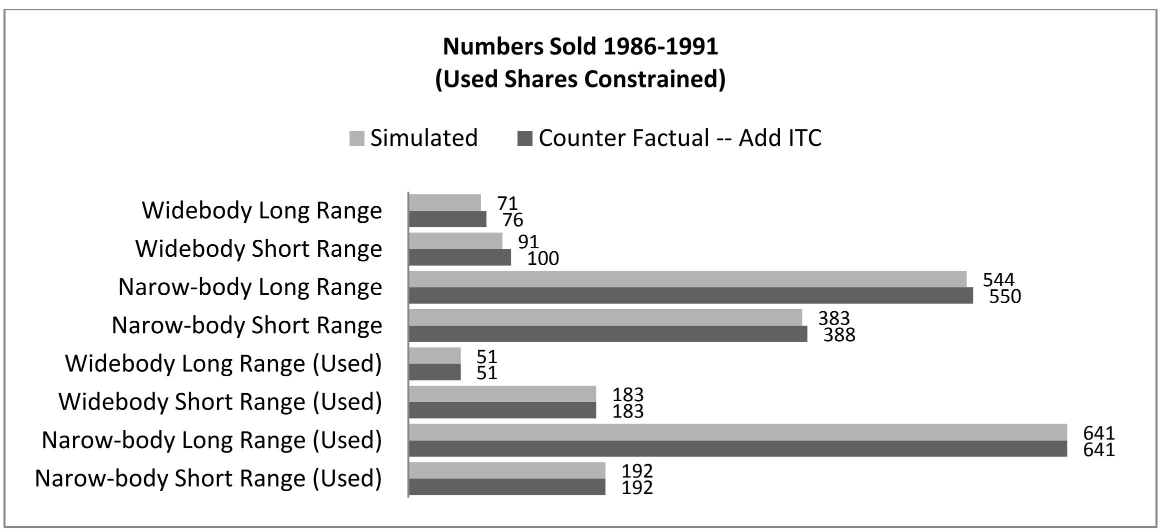


The middle panel of Figure 12 shows the counterfactual under the *Used Shares Constrained* scenario. On average, there was a positive 1% increase in the overall aircraft demand from adding the ITC to the market. The smaller impact of the ITC under *Used Share Constrained* versus the *Used Price and Share Unconstrained* scenario is attributed to the used share constraint. Figure 14, aggregates all of the simulated and counterfactual aircraft sales from 1986 through 1991.

The quantities of used aircraft in Figure 14 are substantially higher than the quantities in Figure 13. This shows the constrained used aircraft sales crowding out new aircraft sales that may have resulted from the ITC. As with Figure 13 changes in quantity follow from price changes in Table 10 and the elasticities from Table 8.

Figure 14, like Figure 13 offers support for the ITC as a method of inducing new capital investment. However, policy support is guarded. The simulations show an increase of only 1% in new aircraft sales by imposing a net 5.3% ITC. The disparity in the used aircraft stock between Figures 13 and 14 raises the possibility that a historically factual large stock of used aircraft might mitigate any positive impact of the ITC reported under the *Used Prices and Shares Unconstrained* scenario in Figure 13.

Figure 14



The bottom panel of Figure 12 shows the impact of adding the ITC under the *Used Prices Constrained* scenario. As with the corresponding constraint under the counterfactual in Section 8.1, the scenario is much more volatile when compared to the middle and upper panel. On average there is a *decrease* in the total aircraft sales of 2% in each quarter. This result can be attributed to the constraint's interaction with the model. The high simulated prices of new aircraft interact with the fixed marginal cost prices and the infinite stock of used aircraft to find unreasonable solutions.[46]

8.3 Changes in Consumer Surplus

As a random utility model, the nested logit allows for the measurement of consumer surplus. Following Hausman, Leonard, and McFadden (1995), the consumer surplus per- air-route , CS_i -- to a constant -- is measured as,

$$CS_i = \frac{1}{|\alpha|} \ln(\sum_{g \in G} D_g{}^{(1-\sigma)}) ,$$

where

$$D_g \equiv \sum_{k \in g} e^{\delta_k / (1-\sigma)} .$$

Figure 16 shows the percent change in consumer surplus for the three used aircraft scenarios under the counterfactual of *removing* the ITC. Figure 16 well reflects the counterintuitive result of complex market interaction discussed in Section 8.1. The top and middle panel show that mean quarterly consumer surplus goes down less than a ¼ percent, .24% in the top panel and .23% in the middle panel, because of the removal of a gross ITC of either 7% through 1980 and 10% from 1981 through 1985. The changing consumer surplus reflects the small pass-through of the tax credit as firms exert their market power to capture as much of the subsidy as possible. Under both scenarios, simulations indicate that four quarters, 1978:1, 1978:4, 1979:1, and 1979:3 would have had *higher* per-route consumer surplus without the ITC.

The bottom panel of Figure 16 shows the counterfactual results for the used price constrained scenario. As with earlier simulations fixing used prices, results are quite volatile and of limited utility.

Nevertheless, the results of the bottom panel are quite consistent with the upper two panels: a very small negative impact on per-route consumer surplus from removing the ITC.

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[46] For completeness, numerical *Used Price Constrained* results are presented in Figure 15 at the end of the paper. As with corresponding Figure 10 from Section 8.1, the overall used aircraft sales are unreasonable.

Figure 16

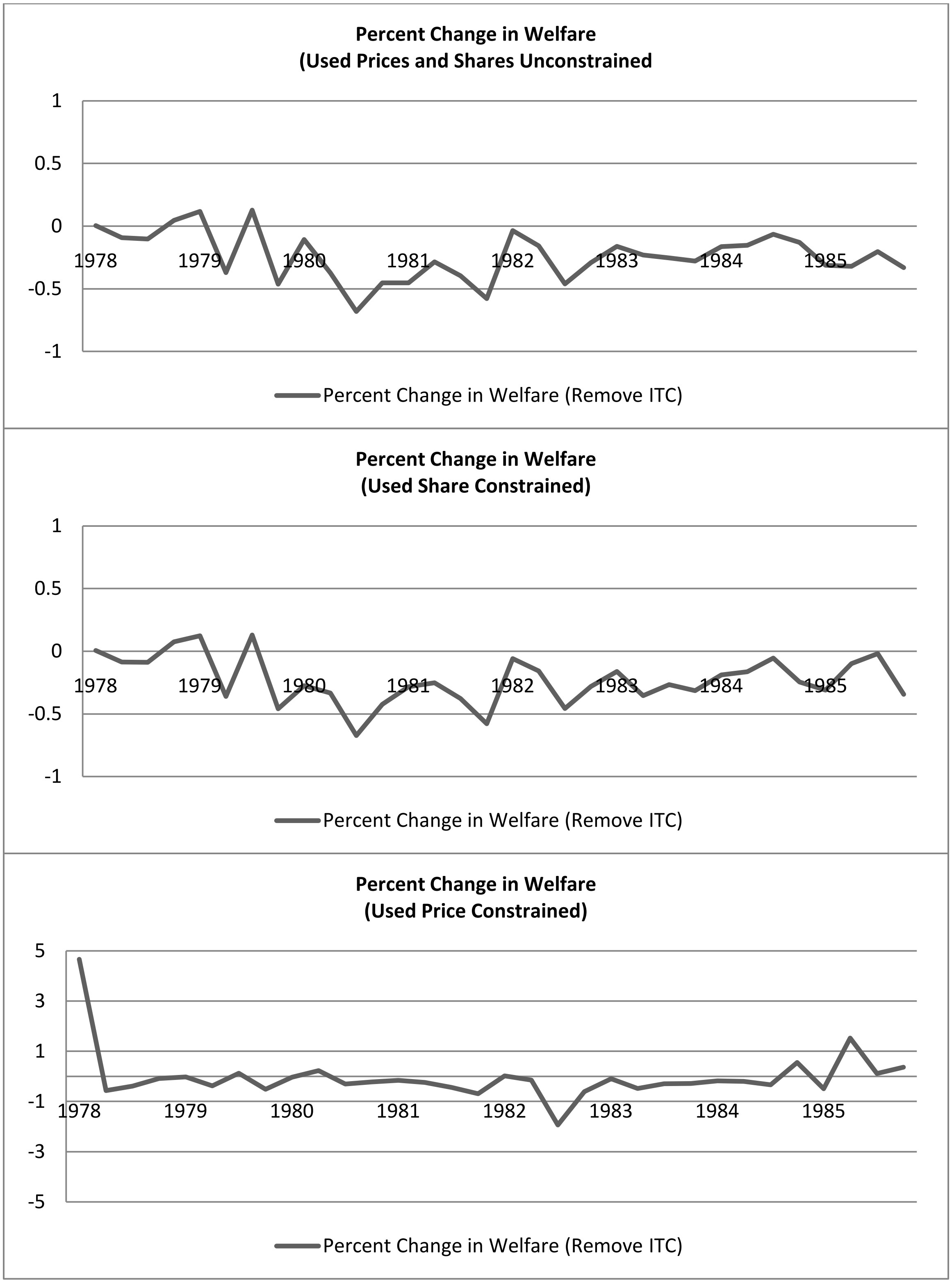
Percent Change in Welfare
(Used Prices and Shares Unconstrained
1
0.5
0
-0.5
-1
1978
1979
1980
1981
1982
1983
1984
1985
Percent Change in Welfare (Remove ITC)
Percent Change in Welfare
(Used Share Constrained)
1
0.5
0
-0.5
-1
1978
1979
1980
1981
1982
1983
1984
1985
Percent Change in Welfare (Remove ITC)
Percent Change in Welfare
(Used Price Constrained)
5
3
1
-1
-3
-5
1978
1979
1980
1981
1982
1983
1984
1985
Percent Change in Welfare (Remove ITC)

Figure 17

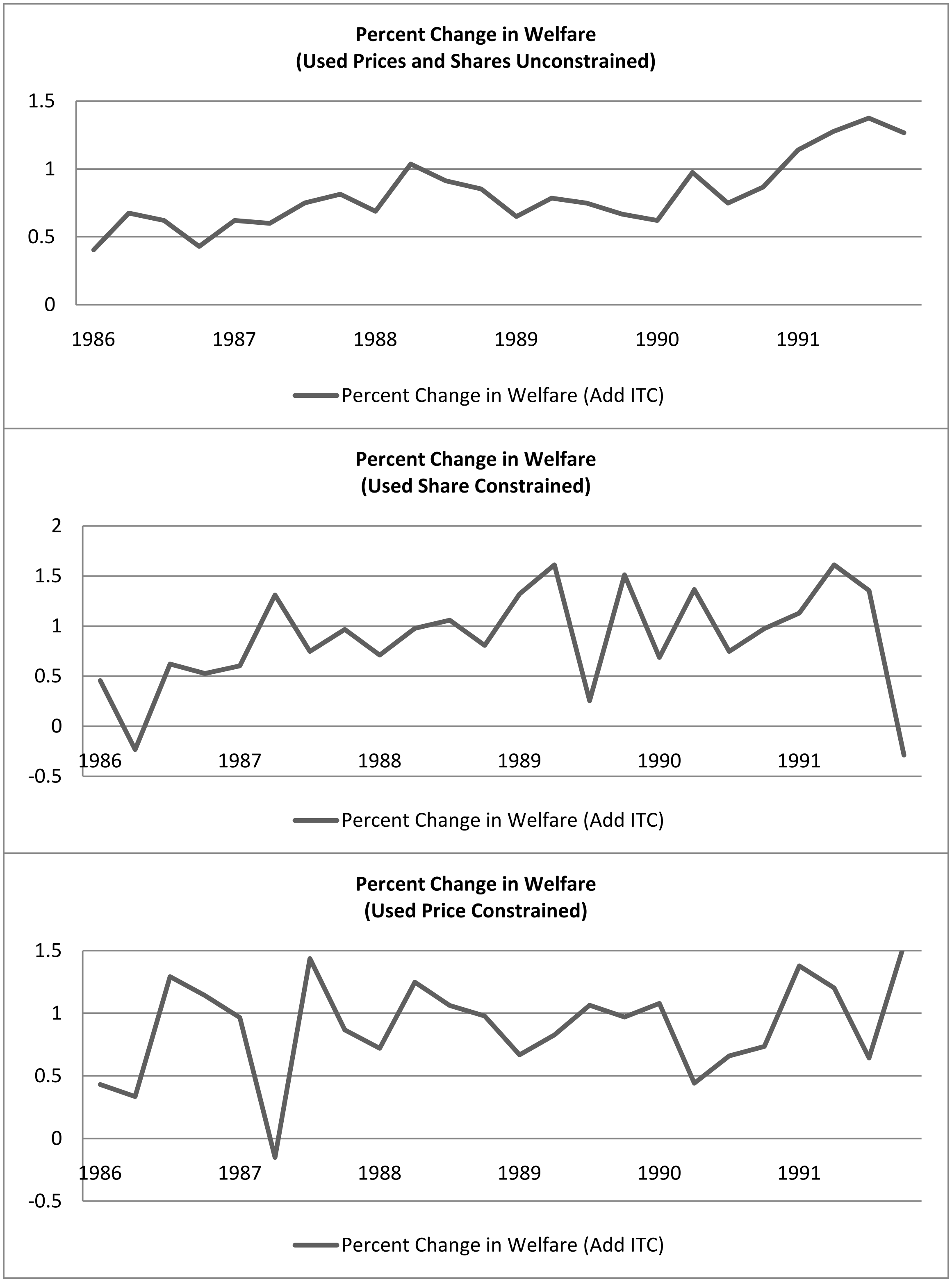
Percent Change in Welfare
(Used Prices and Shares Unconstrained)
1.5
1
0.5
0
1986
1987
1988
1989
1990
1991
Percent Change in Welfare (Add ITC)
Percent Change in Welfare
(Used Share Constrained)
2
1.5
1
0.5
0
-0.5
1986
1987
1988
1989
1990
1991
Percent Change in Welfare (Add ITC)
Percent Change in Welfare
(Used Price Constrained)
1.5
1
0.5
0
-0.5
1986
1987
1988
1989
1990
1991
Percent Change in Welfare (Add ITC)

Figure 17 shows the simulated changes in consumer surplus under the three used aircraft price scenarios for the counterfactual of *adding* the ITC after 1986. The top panel shows an upward trending increasing in consumer surplus. The increasing improvements in consumer surplus closely tracks the level of market competitiveness. When used shares and quantities are unconstrained, per-route consumer surplus would increases an average .81% from a net 5.3% ITC.

Under the fixed used aircraft share constraint, the middle panel, and the fixed used aircraft price constraint, the bottom panel, the model's predictions are less robust. In 1986:2 and 1991:4, the middle panel shows a decrease in consumer surplus. Nevertheless, the average quarterly change in consumer surplus is a .86% increase. Under the used price constraint -- bottom panel -- the average change in quarterly consumer surplus is a similar .89%. As described earlier, the imposed used aircraft constraints introduce a degree of equilibrium instability in the model. These instabilities are reflected in the higher variation of simulated results.

Unidentified air-carrier customers, such as United Airlines or American Airlines, choose to purchase an aircraft for an air-route *i*, *i=(1,…M)*. Under this rubric, the percentage change in consumer surplus from Figures 16 and 17 ultimately reflect per-rout increases, or decreases, in a routes profitability attributable to the ITC. Further analysis of air-route profitability is complicated by the large number of air-routs for which air-carriers do *not* purchase a new aircraft.[47]

The consumer surplus changes presented in Figures 16 and 17 show the major impact market structure has on subsidy pass-though.

9. Conclusion

I found that the historic ITC had important, but perhaps unexpected, effects on the market for commercial aircraft. The simulations indicate that the ITC did *not* substantially affect the total quantity of new aircraft purchases when it was in place, undermining the purported justification for investment tax credits given by policymakers. The estimates suggest that the ITC increased the percentage of new aircraft sales through 1985 by less than 1% per quarter. Adding a hypothetical 10%, net 5.3%, ITC after 1985 would have had a positive, yet modest, increase of between 1% and 3% in aircraft sales. This finding is consistent with Smith's (2010) finding that the "implementation of a tax credit would have a small impact on equilibrium quantities."

[47] See Figure 5.

Nevertheless, in the presence of market power, the ITC's complex interaction with the interrelated demand curves for imperfectly-substitutable aircraft caused aircraft buyers to modify their behavior substantially. Buyers substitute into alternative aircraft groups as a direct result of the ITC. Moreover, in some circumstances, manufacturers are able to raise prices *by more* than the amount of the ITC. That is, buyers paid a higher price after accounting for the ITC than they would have if there had been no ITC. This effectively made the ITC a net *tax* from the buyers' perspective and mitigated any increases in aircraft sales that might have otherwise taken place. In circumstances where the ITC acted as a net tax, the buyers were more likely to purchase wide-body aircraft on which the manufacturers enjoyed greater price-cost markup. The modification of purchasing behavior because of tax policies necessarily causes excess burden, or deadweight loss to welfare. Boeing enjoyed monopoly-like power in the narrow-body long-range market segment until 1982 and McDonnell Douglas in the short-range narrow body market segment until 1983. In both cases new entrants mitigated the market power. The extraordinary markups being enjoyed by Boeing and McDonnell Douglas undoubted contributed to the entry decision of the firms which ended up dissipating the markups they hoped to capture.

This paper shows that the historic ITC distorted the commercial aircraft market. Indeed, the structural modeling of the aircraft industry allows me to show not only, as Goolsbee (1998) found across industries, that the majority of the tax credit went to the manufacturers, but also that manufacturers were able to manipulate the market to their advantage.

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Figure 3A

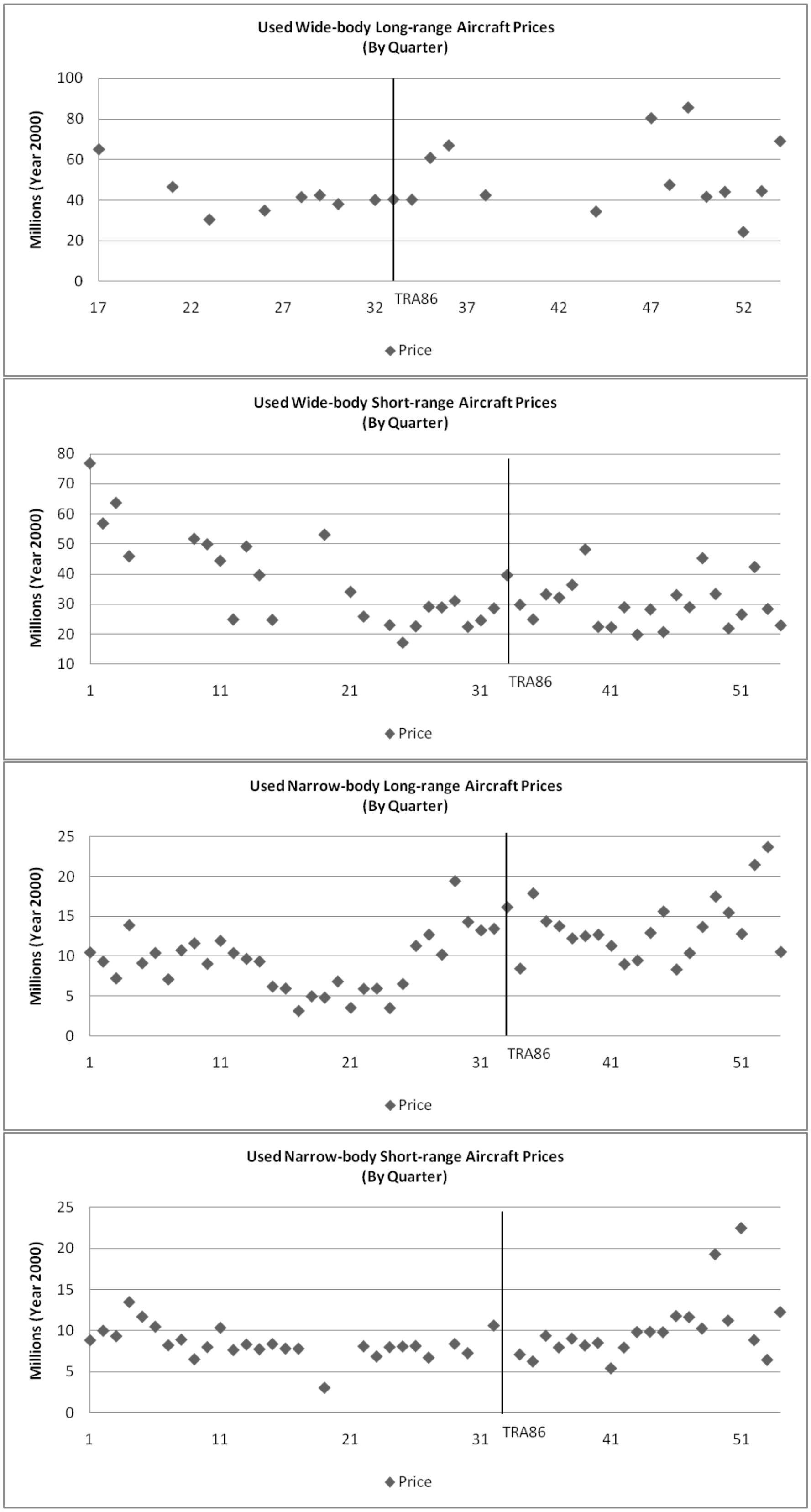
Used Wide-body Long-range Aircraft Prices
(By Quarter)
Millions (Year 2000)
100
80
60
40
20
0
17
22
27
32
TRA86
37
42
47
52
Price
Used Wide-body Short-range Aircraft Prices
(By Quarter)
Millions (Year 2000)
80
70
60
50
40
30
20
10
1
11
21
31
TRA86
41
51
Price
Used Narrow-body Long-range Aircraft Prices
(By Quarter)
Millions (Year 2000)
25
20
15
10
5
0
1
11
21
31
TRA86
41
51
Price
Used Narrow-body Short-range Aircraft Prices
(By Quarter)
Millions (Year 2000)
25
20
15
10
5
0
1
11
21
31
TRA86
41
51
Price

Figure 3B


New Wide-body Long Range Aircraft Prices
(By Quarter)
Millions (Year 2000)
TRA86
Pre-Tax
Post-Tax
New Wide-body Short Range Aircraft Prices
(By Quarter)
Millions (Year 2000)
TRA86
Pre-Tax
Post-Tax
New Narrow-body Long Range Aircraft Prices
(By Quarter)
Millions (Year 2000)
TRA86
Pre-Tax
Post-Tax
New Narrow-body Short Range Aircraft Prices
(By Quarter)
Millions (Year 2000)
TRA86
Pre-Tax
Post-Tax

Figure 5

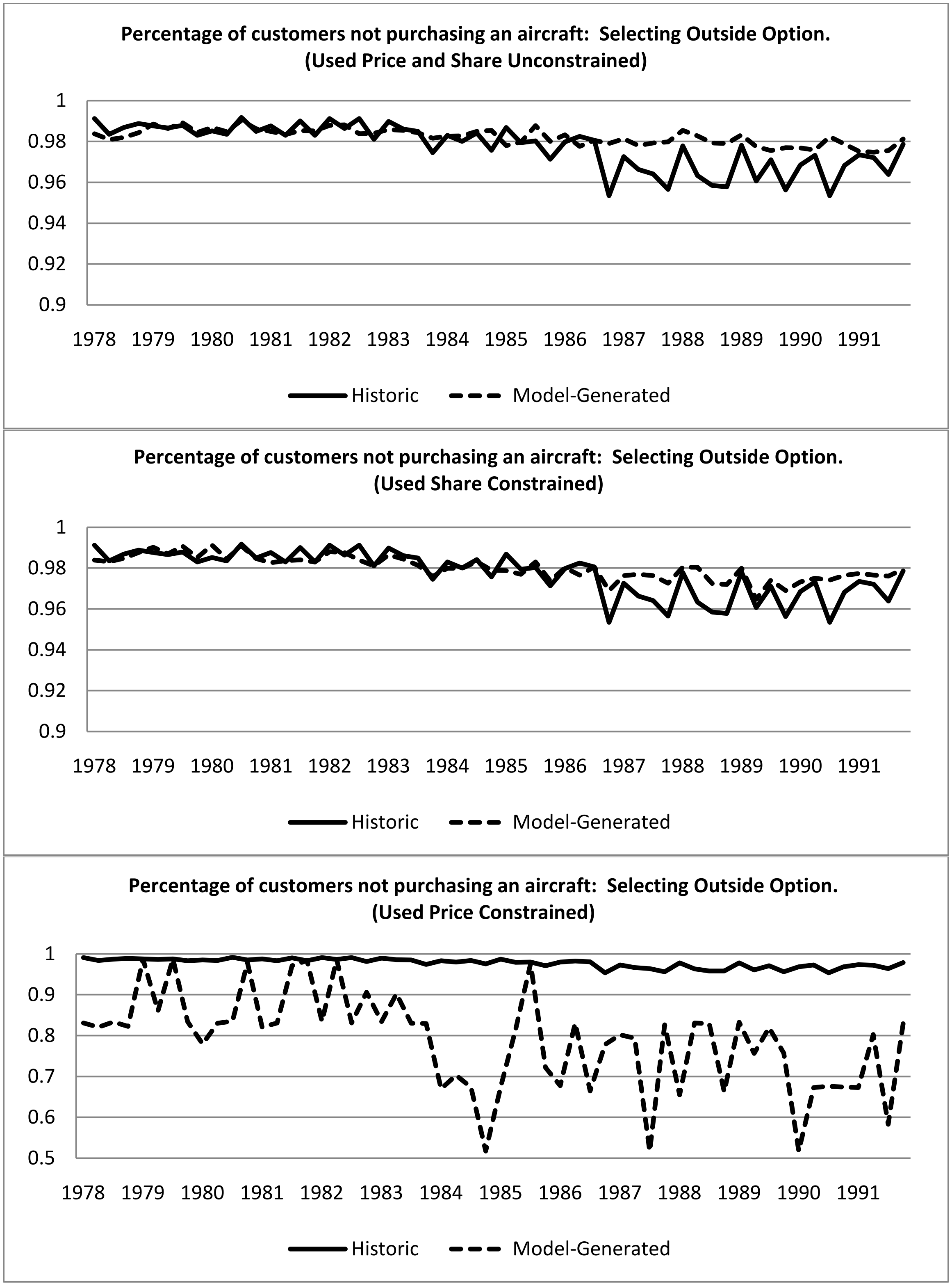
Percentage of customers not purchasing an aircraft: Selecting Outside Option.
(Used Price and Share Unconstrained)
1
0.98
0.96
0.94
0.92
0.9
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991
Historic
Model-Generated
Percentage of customers not purchasing an aircraft: Selecting Outside Option.
(Used Share Constrained)
1
0.98
0.96
0.94
0.92
0.9
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991
Historic
Model-Generated
Percentage of customers not purchasing an aircraft: Selecting Outside Option.
(Used Price Constrained)
1
0.9
0.8
0.7
0.6
0.5
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991
Historic
Model-Generated

Figure 6

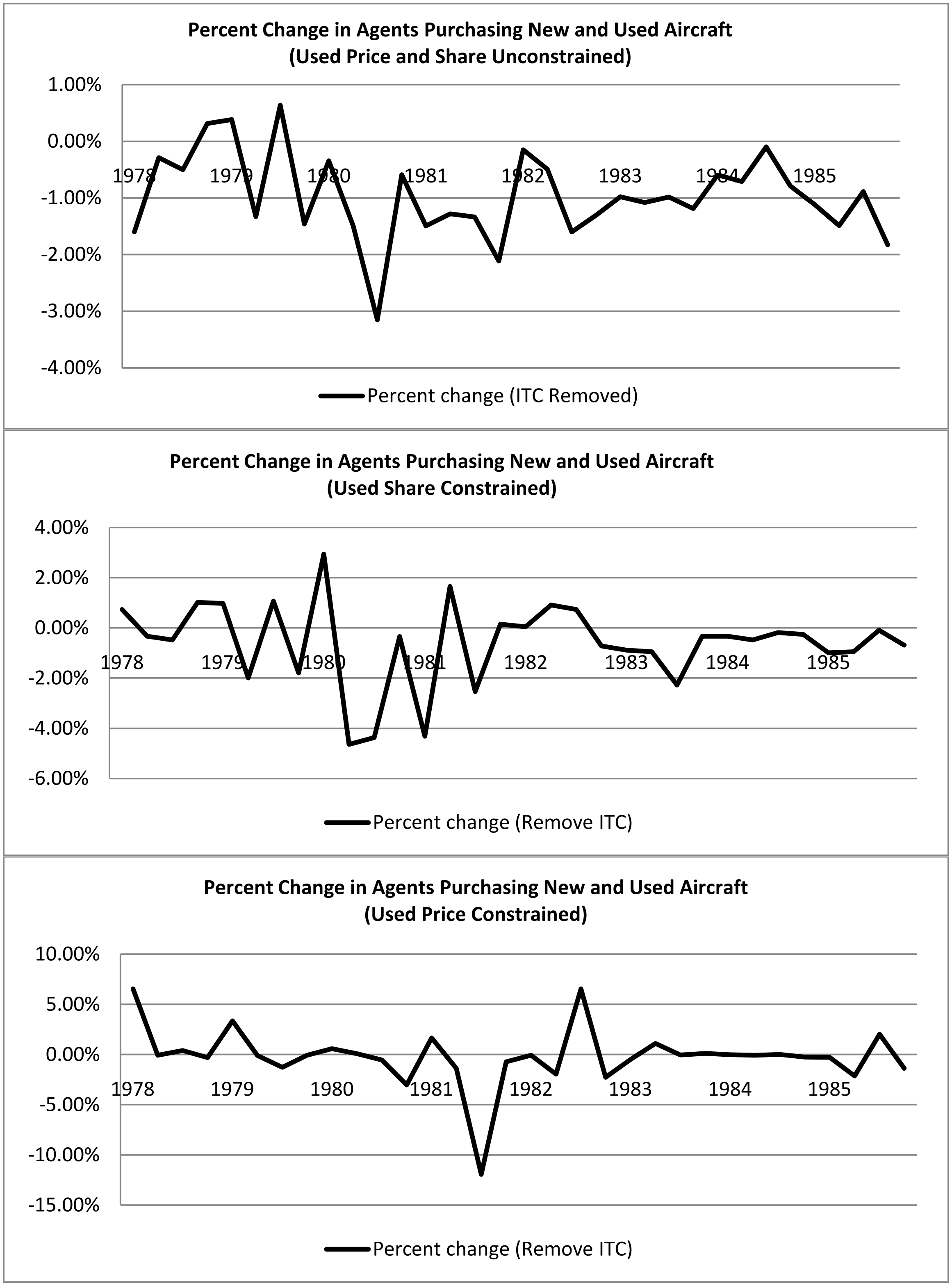
Percent Change in Agents Purchasing New and Used Aircraft
(Used Price and Share Unconstrained)
1.00%
0.00%
-1.00%
-2.00%
-3.00%
-4.00%
1978
1979
1980
1981
1982
1983
1984
1985
Percent change (ITC Removed)
Percent Change in Agents Purchasing New and Used Aircraft
(Used Share Constrained)
4.00%
2.00%
0.00%
-2.00%
-4.00%
-6.00%
1978
1979
1980
1981
1982
1983
1984
1985
Percent change (Remove ITC)
Percent Change in Agents Purchasing New and Used Aircraft
(Used Price Constrained)
10.00%
5.00%
0.00%
-5.00%
-10.00%
-15.00%
1978
1979
1980
1981
1982
1983
1984
1985
Percent change (Remove ITC)

Figure 7(b)

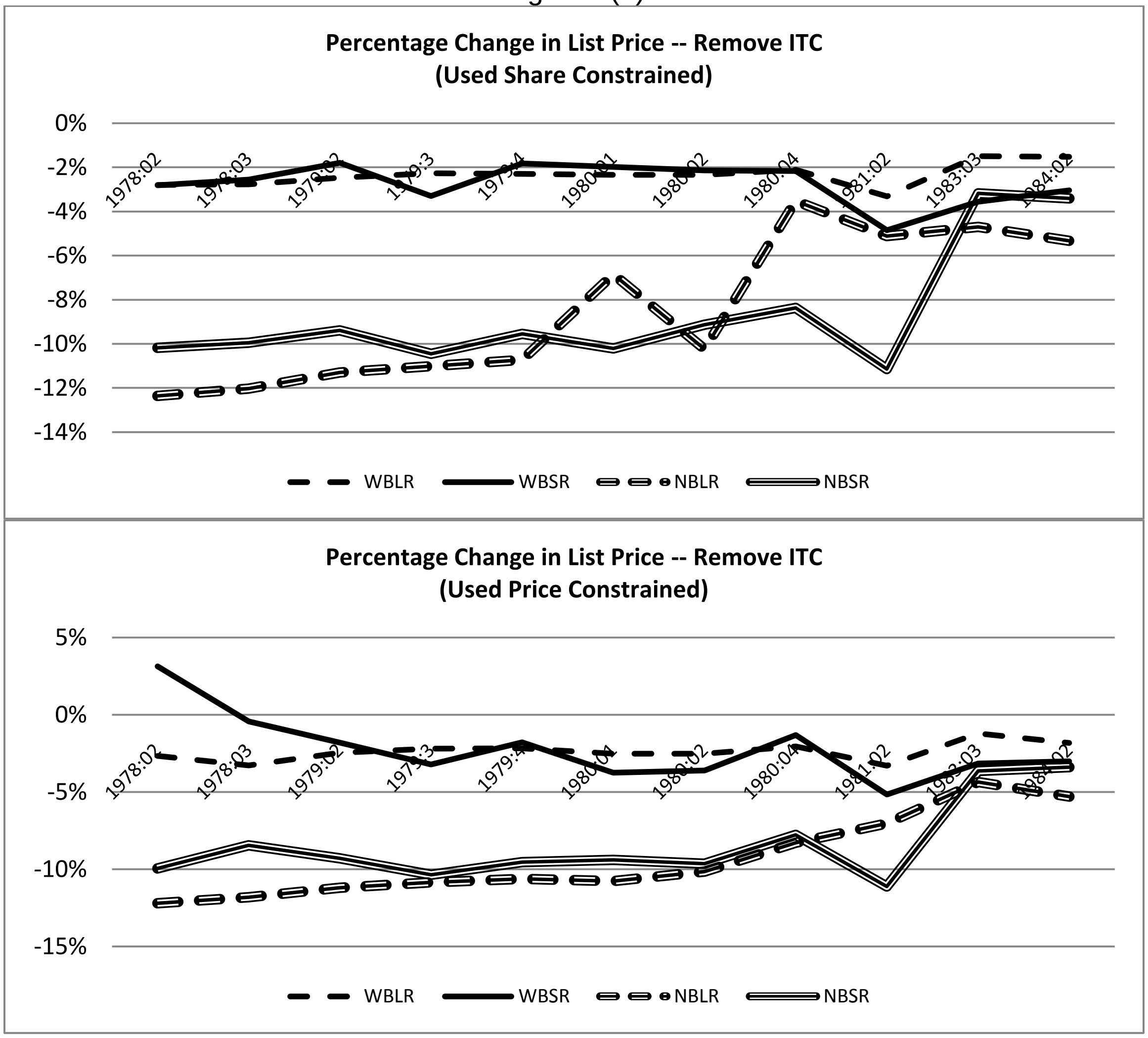

Figure 10

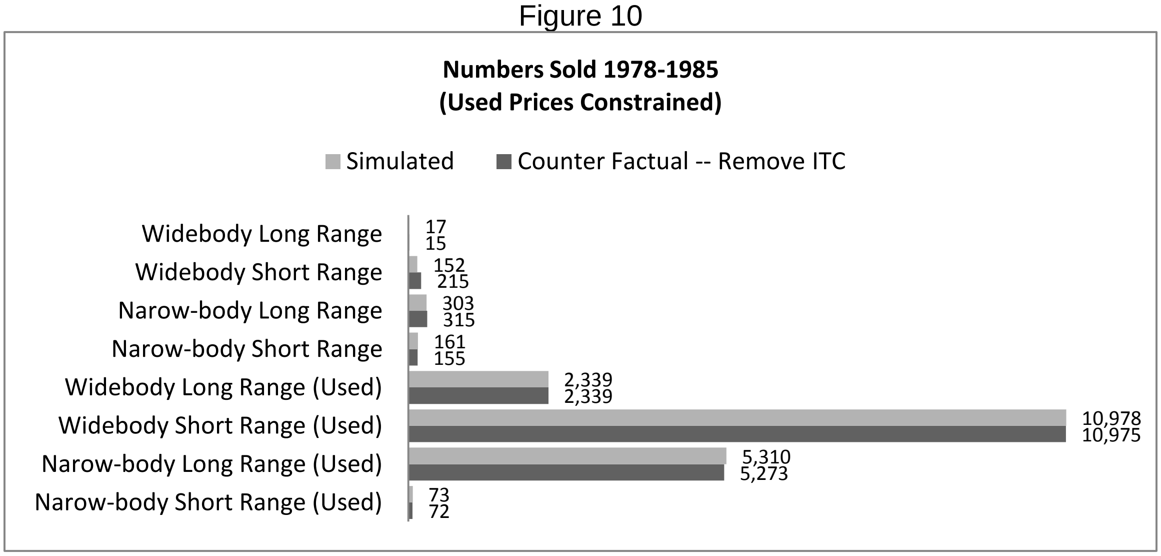

Figure 12

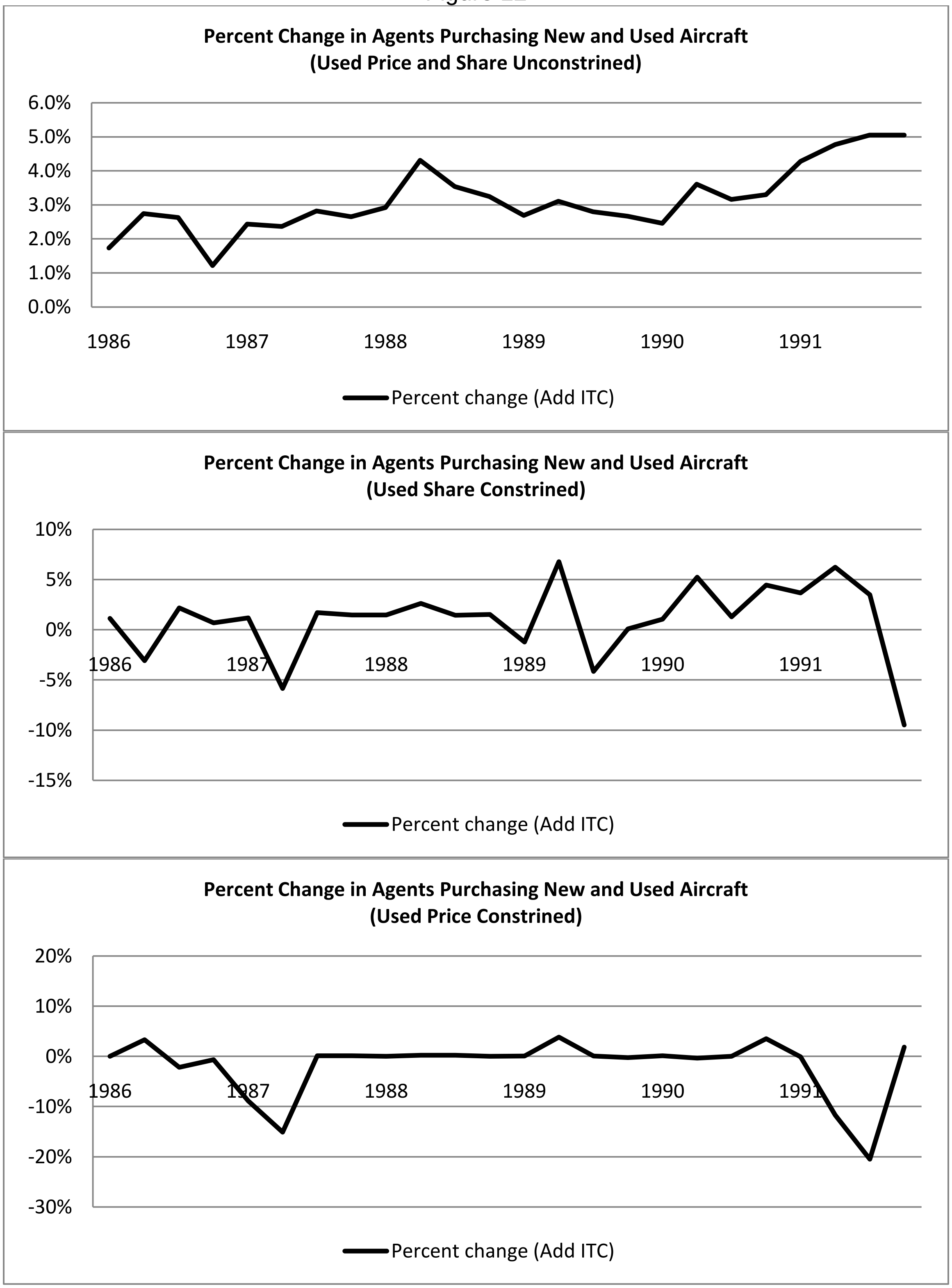
Percent Change in Agents Purchasing New and Used Aircraft
(Used Price and Share Unconstrined)
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
1986
1987
1988
1989
1990
1991
Percent change (Add ITC)
Percent Change in Agents Purchasing New and Used Aircraft
(Used Share Constrined)
10%
5%
0%
-5%
-10%
-15%
1986
1987
1988
1989
1990
1991
Percent change (Add ITC)
Percent Change in Agents Purchasing New and Used Aircraft
(Used Price Constrined)
20%
10%
0%
-10%
-20%
-30%
1986
1987
1988
1989
1990
1991
Percent change (Add ITC)

Figure 15

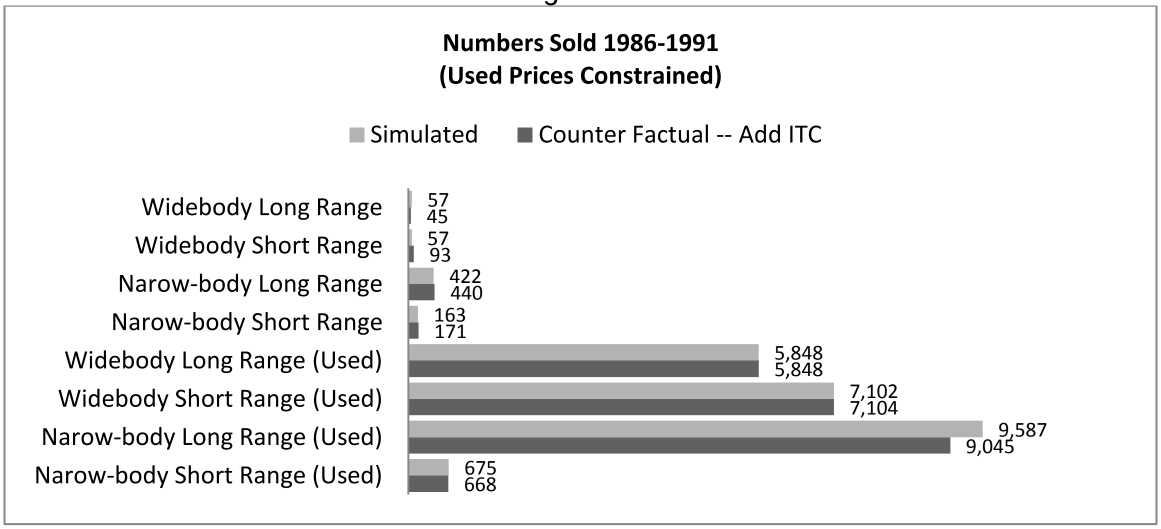
Numbers Sold 1986-1991
(Used Prices Constrained)
Simulated
Counter Factual -- Add ITC
Widebody Long Range
Widebody Short Range
Narow-body Long Range
Narow-body Short Range
Widebody Long Range (Used)
Widebody Short Range (Used)
Narow-body Long Range (Used)
Narow-body Short Range (Used)
57
45
57
93
422
440
163
171
5,848
5,848
7,102
7,104
9,587
9,045
675
668

Table 11

Narrow-body Short-Range
Number of Aircraft Sold

	1	2	3-5	6-10	>10
727-200A	12.95	12.91	13.16	12.96	12.27
727-200F	13.53	10.90			
BAE200	13.93	14.27	12.61	6.30	
DC9-30	10.46	11.33	10.11		
DC9-50	11.30	12.16	11.08		
MD-81	17.77	16.83	15.68	15.82	
MD-82	18.55	19.15	18.57	17.07	20.06
MD-88	19.04	21.35	18.82	23.28	25.41
F100	17.01	19.75	19.39	15.65	

Wide-body Short-range
Number of Aircraft Sold

	1	2	3-5	6-10	>10
A300B4-100	29.86		27.09		
A300B4-200			28.19		
A300B4-600	50.72		58.59		48.67
A310-300P	50.17	51.50			
767-200	30.68	30.63	30.64	31.63	
767-300	49.73	52.66	41.65	54.42	
DC10	33.52	35.66			
DC10-30F	47.40	50.84	25.42		
L1011-1	29.83	30.48	32.28		

Narrow-body Long-Range
Number of Aircraft Sold

	1	2	3-5	6-10	>10
A320	25.03		26.27	34.01	32.65
737-200	11.54	10.73	11.32	15.07	12.13
B737-200F	13.53	10.90			
B737-300	19.42	20.56	19.80	22.07	22.57
B737-400	23.03	23.63	21.46	25.16	26.69
B737-500	17.67	17.38	20.11	22.29	
757	30.37	32.04	32.14	37.07	39.29
757F	30.57		30.24		
MD-83	22.95	20.33	20.26		

Wide-body Long-range
Number of Aircraft Sold

	1	2	3-5	6-10	>10
747-200	59.60	63.74	63.72		
B747-200HF	62.81	68.90	49.09		
B747-400	95.35	93.00	109.99	107.64	
747S	44.65	43.22			
767-200E	41.76	42.08	42.93		
767-300E	53.88	51.88	46.98		
MD-11		66.86	68.19		
MD-11F	88.05	81.85			
L1011-500	34.14	32.10	37.44		