Airbus versus Boeing Revisited: International Competition in the Aircraft Market

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Abstract:

This paper examines international competition in the commercial aircraft industry. We estimate a discrete choice, differentiated products demand system for wide-body aircraft and examine the Airbus-Boeing rivalry under various assumptions on firm conduct. We then use this structure to evaluate two trade disputes between the United States and European Union. Our results suggest that the aircraft prices increased by about 3 percent after the 1992 U.S. – E.U. agreement on trade in civil aircraft that limits subsidies. This price hike is consistent with a 7.5 percent increase in firms' marginal costs after the subsidy cuts. We also simulate the impact of the future entry of the Airbus A-380 super-jumbo aircraft on the demand for other wide-bodied aircraft, notably the Boeing 747. We find that the A-380 could reduce the market share of the 747 by up to 14 percent in the long range wide-body market segment (depending upon the discounts offered on the A-380), but would reduce the market for Airbus's existing wide-bodies by an even greater margin.

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1. Introduction

One of the recurring trade disputes between the United States and Europe concerns the rivalry between Airbus and Boeing in the market for wide-body aircraft. Airbus first began production of aircraft in the early 1970s with substantial financial assistance from European governments. As Airbus succeeded in making inroads into many of Boeing's markets, Boeing alleged that Airbus benefited from unfair subsidies and has pressured U.S. trade authorities to counteract Europe's financial support. As a result, the United States and European Community signed an agreement on trade in civil aircraft in 1992 that limited government subsides for aircraft production. This agreement, however, has come under new strain as Airbus introduces the A-380 super jumbo aircraft designed to compete directly against the Boeing 747.

Competition in the wide-bodied aircraft industry has attracted attention not just because of the controversy surrounding the Airbus subsidies, but because of the industry's unusual market structure, in which economies of scale are enormous relative to market demand. The aircraft sector provides a textbook example of an industry in which trade policy could affect the strategic interaction between a domestic and an international rival and shift profits in favor of the domestic firm, as proposed in Brander and Spencer's (1985) canonical model of strategic trade policy. Previous studies of the commercial aircraft market, notably Baldwin and Krugman (1987), Klepper (1990, 1994), and Neven and Seabright (1995), used calibrated simulations to analyze the competitive interaction of Airbus and Boeing. These simulations focused on Airbus's impact on the costs and profits of its competitors and on consumer surplus as a way of evaluating the welfare effects of Airbus's market presence.

This paper takes an empirical approach to examining international competition and trade disputes in the wide-body aircraft market. We employ Berry's (1994) method of estimating demand in an oligopoly market with differentiated products using data on commercial aircraft prices, sales, and characteristics from 1969 to 1998.[1] This approach provides us with estimates of price and cross-price elasticities of demand, which allow us to assess how closely related in demand various aircraft are. The demand system, combined with an assumption on firms' (static) market conduct, also yields estimates of price-cost markups, allowing us to determine whether competitive pressures have increased in this segment of the market as a result of Airbus's entry and Lockheed and McDonnell-Douglas's exit.

We then focus on two aspects of the international rivalry between Airbus and Boeing. First, we examine whether the 1992 U.S-E.U. agreement on trade in civil aircraft limiting aircraft subsidies had a significant impact on pricing in the aircraft market. We determine that the agreement appears to have raised the prices of both Airbus and Boeing aircraft by about 3 percent in the narrow- and wide-body market. Our structural model and estimates of the wide-body market suggest that these price increases are consistent with a 7.5 percent rise in the marginal cost of production after the subsidy cuts. Second, we use our demand estimates to estimate the impact of the introduction of the A-380 on the prices and market shares of other wide-body aircraft, notably the Boeing 747. We find that the A-380 can be expected to have a significant negative effect on the prices and sales of the 747, but an even greater adverse effect on demand for Airbus's existing wide-body aircraft (the A-330 and A-340). This result highlights the fact that as Airbus and Boeing expand their product line over time, profit maximization by multi-product firms becomes more complicated as demand for a firm's existing models is sensitive to the price and characteristics of its new models.

[1] Our approach of estimating demand is in the spirit of Berry, Levinsohn, and Pakes (1999) and Goldberg (1995) who examine the impact of trade restraints in the automobile industry.

One recent study that combines elements of demand estimation and industry simulation is Benkard (2000a). He estimates demand parameter for wide-body aircraft and uses them with estimates of a cost function that accounts for learning by doing to compute numerically the dynamic equilibrium in the aircraft market and simulate the evolution of the industry. He also simulates the welfare implications of an antitrust policy that places an upper bound on the market share that any one firm can achieve and finds that this harms consumers. Although our approach to estimating market demand is similar (we allow for additional market segmentation in the market for medium- and long- range wide-body aircraft, an important differentiation according to our empirical results), our paper ultimately addresses a different set of issues.

Section 2 of this paper discusses the institutional detail of the aircraft industry, estimates discrete choice demand system, and calculates the markups implied by various assumptions on firm conduct. Section 3 estimates the effect of the 1992 U.S.-E.U. aircraft trade agreement on aircraft pricing, and simulates the effects of the A-380 entry on the market share and prices of existing wide-body aircraft. Section 4 concludes.

2. Structural Estimates of Aircraft Demand and Markups

The market for aircraft is typically divided into two product categories: narrow-body and wide-body aircraft. Narrow-body aircraft are single aisle, short-range aircraft (up to 6,000 km) that typically carry between 100 to 200 passengers. The leading aircraft in this category are the Boeing 737, the Boeing 757, and the Airbus A-320. Wide-body aircraft are double aisle, medium to long-range aircraft (up to 14,000 km) that can carry between 200 to 450 passengers. The leading aircraft in this category are the Boeing 747, the Boeing 777, and the Airbus A-300. Narrow- and wide-body aircraft are imperfect substitutes for one another because the planes are designed to serve different markets, and competition is much more intense within each category than between them. Figure 1 plots the typical number of seats and the range of various aircraft and clearly indicates how localized the competition is within the narrow-body and wide-body segment.

We focus mainly on the wide-body segment of the aircraft industry in part because most of the international trade disputes have centered on competition in this product range. The increase in international travel since the 1970s has made this a rapidly growing segment of aircraft demand. The wide-body market has also been very profitable: the Boeing 747, for example, is said to account for as much as a third of Boeing's entire profits in certain years. As a result, Airbus, for example, entered the aircraft market in this segment with the A-300 in 1974, and only later began competing in the narrow-body market with the launch of the A-320 in 1988. There are fewer product lines in wide-body segment of the market, and the number of aircraft sold is much smaller than in narrow-body segment. The cumulative output of the best selling wide-body Boeing 747 has only reached about 1,185 units in 1998 (it was introduced in 1969), and the best selling Airbus aircraft A300 sold only 481 units between 1974 and 1998. As a result, competition tends to be more intense in wide body market because, since from the firm's perspective, each additional sale generates valuable revenue. In contrast, narrow-body planes often sell well above 1,000 units over their lifespan, with Boeing 737 selling over 3,200 units until 1998.

2.1 Demand for Wide-Body Aircraft

The structure of our aircraft demand system is based on the discrete choice random utility framework outlined in Berry (1994). This framework enables us to estimate the demand for a differentiated product using data on sales, prices, and other product attributes, without observing the purchases made by individual consumers. In this framework, consumers (airlines) have a choice of purchasing either one of several wide-body aircraft or an outside good, in this case a narrow-body aircraft. Utility from the outside good is normalized at zero. The total potential market therefore consists of all narrow-body and wide-body aircraft purchased in a given year.

We model each wide-body aircraft as a bundle of characteristics that airlines value. These characteristics include price, range, passenger seating, and takeoff weight. Our framework also allows the airlines to value aircraft characteristics that are not directly observed. Airline i's utility of purchasing product j (u_{ij}) can be expressed as a linear function of aircraft j's characteristics and tastes idiosyncratic to airline i:

$$u_{ij} = x_j \beta - \alpha p_j + \xi_j + \tau_{ij}$$

where x_j is a vector of product j's attributes, and p_j is aircraft price. ξ_j represents aircraft j's characteristics that the airlines value, and τ_{ij} captures airline i's specific taste for aircraft j, both of which are not observed by the econometrician. The mean utility level that product j yields to airlines is denoted by δ_j, so that $\delta_j \equiv x_j \beta - \alpha p_j + \xi_j$. Note that in this framework all variation in the valuation of aircraft across airlines stems from the unobserved additive taste term τ_{ij}.

We allow consumer-specific tastes to be correlated across products with similar characteristics by using a nested logit demand model. We group wide-body planes into two distinct market segments g: medium-range and long-range wide-body aircrafts.[2] Consumers also have an option of not purchasing a wide-body plane and purchasing the outside good. We can then rewrite the consumer taste parameter τ_{ij} as $\tau_{ij} \equiv v_{ig}(\sigma) + (1-\sigma)\varepsilon_{ij}$. Term ε_{ij} captures consumer tastes that are identically and independently distributed across products and consumers according to the extreme value distribution. Term v_{ig} captures the common taste that airline i has

[2] The medium-range wide-bodies include the Boeing 767 and the Airbus A-300 and A-310. The long-range wide-bodies include the Boeing 747 and 777, the Airbus A-330 and A-340, and the MD-11.

for all aircraft in market segment g.[3] The common taste depends on the distribution parameter σ $(0 \le \sigma < 1)$, which indicates the degree of substitutability between products within a market segment. When σ is zero, consumer tastes are independent across all aircraft and there is no market segmentation. The higher the σ, the more correlated the consumer tastes are for products within the same market segment and the competition among products is stronger within than across market segments.[4]

Given the set of available aircraft, airlines are assumed to select the aircraft that gives them the highest utility.[5] Consumer i will choose aircraft j if:

$u_{ij} \ge u_{ik}$.

Given the distributional assumptions on consumer tastes and functional form for utility, we can aggregate over individual consumer purchases to obtain predicted aggregate market share s_j of aircraft j:

$$s_j(\delta,\sigma) = \frac{e^{\delta_j/(1-\sigma)}}{D_g} \frac{D_g^{\,1-\sigma}}{(\sum_g D_g^{\,1-\sigma})} \qquad (1)$$

$$where\ D_g \equiv \sum_{j\in g} e^{\delta_j/(1-\sigma)}$$

The first term in this expression is aircraft j's market share in its market segment, while the second term is the market share of a market segment g in the overall aircraft market. Since the

3 Since ε_{ij} is an extreme value random variable, τ_{ij} is an extreme value random variable (Berry (1994)).

4 In his wide-body aircraft demand estimates, Benkard (2000a) also allows for market segmentation between the outside good and wide-body market, but does not distinguish between the medium- and long-range segments of the wide-body market. Our estimates of σ indicate the importance of allowing for the additional market segmentation. In addition, he estimates the model using data from 1975 to 1994 whereas our data span 1969 to 1998. The additional years of data are important because the A-330, A-340, and Boeing 777 only enter the market in 1993 and 1995.

5 Note that this framework allows an airline to purchase only one aircraft at a time. Airlines often bundle their orders and concurrently purchase several aircraft. Since we do not observe individual purchases, we cannot address this issue. Hendel (1999) explicitly models and estimates the demand for computers allowing for multiple purchases. We also do not address inter-temporal demand issues relating to the fact that aircraft are durable goods.

outside good yields zero utility by assumption, δ_0 is 0 and D_0 is 1. We can invert the predicted market share for product j to obtain an analytic expression for mean utility level δ_j as a function of demand parameters and distributional parameter σ:

$$\ln S_j - \sigma \ln S_{j|g} - \ln S_o = \delta_j(S,\sigma) \equiv x_j\beta + \alpha p_j + \xi_j$$

Rearranging the above equation yields our estimating equation for demand:

$$(2) \quad \ln S_j - \ln S_o = x_j\beta + \alpha p_j + \sigma \ln S_{j|g} + \xi_j$$

where S_j is the observed market share of product j, S_0 is the observed market share of the outside good, and $S_{j|g}$ is the observed market share of product j within its market segment g.

2.2 Estimation Results

We estimate demand equation (2) using annual product level data on aircraft prices, sales, and characteristics from 1969 to 1998. The data cover worldwide sales by Airbus, Boeing, McDonnell Douglas, and Lockheed Martin in the wide-body market segment.[6] Table 1 presents the descriptive statistics of the data; further information on sources and data construction are described in the Data Appendix.

There are two issues in estimating (2). First, although the econometrician does not observe aircraft quality ξ_j, the aircraft producers likely set the price of product j to reflect the product quality. The aircraft prices are therefore likely correlated with unobserved quality. Second, the within-group market share $S_{j|g}$ are also likely correlated with ξ_j. We therefore instrument for the two variables with two types of instruments: cost-shifters (hourly manufacturing wages in the E.U. and the U.S. and the price of aluminum), and the characteristics of the rival aircraft x_{-j} averaged over the entire wide-body market and averaged over products

[6] Our sample includes all wide-body planes: Boeing 747, Boeing 767, Boeing 777, DC-10, MD-11, L-1011, A-300, A-310, A-330, A-340.

within each market segment. Cost shifters affect product prices, but are uncorrelated with product j's unobserved quality. Similarly, rival products' characteristics influence the market share and prices of rival aircraft, and through strategic interaction, also affect the pricing decisions and market shares of the product j in question. However, they are not econometrically correlated with product j's unobserved quality ξ_j. The key identifying assumption is that product attributes x_j are not correlated with ξ_j. This is arguably a questionable assumption, but we can test the validity of these instruments in our estimation. The demand equation is linear in all parameters and the error term, so it can be estimated by two-stage least squares.

Table 2 presents the estimation results. Columns 1 and 2 report the OLS estimates of the demand parameters, and columns 3 and 4 control for unobserved product quality using product fixed-effects estimation. Columns 5 and 6 report two-stage least squares estimates that rely on only rival products' mean attributes, only cost shifters, and both rival products' mean attributes and cost shifters as instruments, respectively. The IV estimates are not very sensitive to the choice of the instrument set, so we focus our discussion on column 7 that uses the full instrument set.[7]

Accounting for the endogeneity of price and within market segment market share affects the estimated parameters. For example, the OLS estimate of the price coefficient in column 2 is -.0033, while the coefficient on price is negative and statistically different from zero in the fixed effects (-.0224) and IV regressions (for example, -.0195 in column 7). These estimates are in line with our expectation of upward bias in the OLS coefficient. The coefficients on other product attributes seem sensible. Focusing on the IV estimates in column 7, the additional take-off weight has negative impact on aircraft market share, while additional seating and range are

[7] The overidentification test in column 5 and 7 fails to reject that the instrument set is not correlated with the error term. We cannot perform an overidentification test in column 6 because the system is just identified.

positively related to aircraft market share. This is not surprising, since extra weight (conditional on all other characteristics) implies a higher fuel use and higher operating costs for airlines. Note that the coefficients on these characteristics are not estimated very precisely, which is not surprising given the low number of products and the fact that aircraft manufacturers do not change typical characteristics for a given aircraft model very frequently.

The estimated value of σ is 0.41. The estimate is significantly different from zero, which suggests that planes within the medium- and long-range market segment are better substitutes for each other than planes across the market segments. This has important implications for competition among various aircraft. If a new product is introduced into a long-range wide-body market (for example, Airbus A-380), it will erode the market share of the products such as Boeing 747 and Airbus 340 more than the market share of Boeing 767, which competes mostly with medium-range planes.

Similarly, if, for example, the Boeing 747 increases its price, this increases the market share of its rivals in the long-range wide-body market segment by more than the market share of its competitors in the medium-rage market segment. To address the substitutability of products more formally, we use the estimates for the coefficient on prices α and substitutability parameter σ from column 7 to calculate the own and cross-price elasticities of demand derived from market share equation (1):

$$\eta_{j,j} = \frac{\partial s_j}{\partial p_j}\frac{p_j}{s_j} = -\alpha p_j s_j + \alpha p_j \left(\frac{1}{(1-\sigma)} - \frac{\sigma}{(1-\sigma)} s_{j|g}\right)$$

$$\eta_{j,k} = \frac{\partial s_j}{\partial p_k}\frac{p_k}{s_j} = -\alpha p_k s_k \quad if \;\; j \neq k \quad k \notin g, j \in g$$

$$\eta_{j,k} = \frac{\partial s_j}{\partial p_k}\frac{p_k}{s_j} = -\alpha p_k s_k \left(\frac{\sigma}{(1-\sigma)}\frac{s_{k|g}}{s_k} + 1\right) \quad if \;\; j \neq k \quad j,k \in g$$

where η_{jj} is product j's own-price elasticity of demand, η_{jk} is the cross-price elasticity between product j and k, and differs depending upon whether the products belong to the same market segment.

Table 3 presents the means and standard deviations of the elasticities over time in columns 1-3. First, the average estimate of the own-price elasticities reported in column 1 suggests that a 1 percent increase in the price lowers a plane's market share by 2 percent. The average demand elasticity increases in absolute value over time, averaging about -1 in the early 1970s to -2.8 in the late 1990s. Within a year, the own-price elasticities also differ significantly across products, for example, ranging from -1.6 for Boeing 767 to -4.1 for Boeing 747 in 1998. Second, the estimates of the cross-price elasticities reported in column 2 (for products in the same market segment) and 3 (for product in different market segments) suggest that products within each market segment are closer substitutes for each other than products across the segments. For example, the average cross-price elasticity suggests that a 10 percent increase in the price of a product leads on average to 5.4 percent increase in the market share of the products in the same segment and only 1 percent increase in the market share of the product in a different market segment.[8] Note that all these elasticity estimates are much lower than the estimates of substitutability of foreign and domestic goods used in the trade literature trying to explain the home market bias in consumption surveyed by Obstfeld and Rogoff (2000).

2.3 Aircraft Markup Estimates

We can obtain consistent estimates of product demand without assuming the mode of competition among the firms. However, in order to calculate firm markups we need to assume a

[8] The cross-price elasticities actually decline over time. This is not surprising, since the number of products in the market has increased. Thus, the effect of a price increase of a product on the market share of *each* of its competitors diminishes.

specific form of firm conduct. In each period (omitting time subscripts), firm f maximizes its profits given by:

(3) $$\pi_f = \sum_{j \in F_f} p_j s_j(p)M - \sum_{j \in F_f} C_j(s_j(p)M)$$

where M is total market size, C_j is cost of producing product j, and all other notation follows from previous notation. This profit function accounts for the important fact that Airbus, McDonnell Douglas, and Boeing are multi-product firms that are selling several products during most time periods. Thus, when Boeing considers lowering a price of one of its products, this will not only reduce the market share of Airbus's products, but might also undercut the sales of Boeing's other products. Boeing might then lower its prices by less than in a situation when it only sells one product.

There is mixed evidence on whether aircraft producers compete in prices or quantities. Anecdotal evidence on the widespread use of price discounts and favorable financing options suggests that aircraft companies compete in prices. As an example, a Harvard Business School case study reports significant underbidding between Boeing and Airbus, and cites the former Airbus Chairman Alan Boyd admitting to "pricing for market share...we had to do it in order to get our feet in the door." Yet price competition might be a questionable assumption during the periods when firms face capacity constraints. Tyson (1992) reports that the industry sources claim that capacity constraints were not binding during the 1980s. Although this informal evidence tends to support price competition, given the uncertainty we compute markups based on Bertrand and Cournot mode of competition.

Assuming that firms compete in prices, first-order conditions for profit maximizing firm f with respect to product j yield:

$$\sum_{k \in F_f} (p_k - \frac{\partial C_k}{\partial s_k}) \frac{ds_k}{dp_j} + s_j = 0$$

To derive a pricing equation for each product j, we use vector notation. Let p denote a Jx1 price vector, c a Jx1 vector of marginal costs, and s a Jx1 vector of market shares of all products offered at time t (time subscript is omitted in the notation). Let Ω be a JxJ matrix whose element in row j and column k equals $-\frac{\partial s_k}{\partial p_j}$ if aircraft j and k are produced by the same firm and 0 otherwise. We can then rewrite the first order profit maximizing conditions in vector form as:

(4) $p = c + \Omega^{-1} s$

Using equation (4), our demand parameter estimates, and the data on prices and market shares enables us to calculate the markup margin over price ($(p_j - c_j)/p_j$) for each product j. Note that in the case of a single-product firm, the markup margin over price equals the inverse of the products own price elasticity.[9]

Columns 4-8 of Table 3 report the implied average markups over price over time under various assumptions on the mode of competition. Column 4 presents the implied markups when we assume that a different firm produces each product, column 5 presents markups that account for multi-product firms, and column 6 shows the percentage difference between column 5 and 4. First, focusing on the multi-product Bertrand estimates in column 5, the average markup margins decline from .89 in the early 1970s to .45 in the late 1990s. This indicates that the competition in the aircraft market has increased substantially over time despite the presence of only a few firms. These estimates (especially in the later periods) seem sensible. For comparison, the price-cost estimates in the automobile industry range from .24 to .40, despite the fact that the auto industry is much less concentrated and has many more products. Second, the multi-product firm markups

[9] Appendix 1 derives the equilibrium pricing equation for Cournot competition.

are on average 11 percent higher than single-product firm markups, but the difference becomes much more pronounced over time. While no firm offered more than one wide-body aircraft in the 1970s, Airbus and Boeing introduced new products starting in the 1980s. As a result, the markups accounting for multi-product firms are on average 22 percent higher than the single-firm markups in the 1990s. Finally, over time, the markup estimates are becoming less sensitive to whether firms compete in prices or quantities. Column 7 presents the multi-product firm Cournot markup margins over price and column 8 depicts the average difference between the Cournot and Bertrand markups (as a share of Bertrand markup). The difference in markups drops from about 15 percent in the early 1970s to 8 percent from the mid 1980s onwards.

We should emphasize that these markups ignore any pricing dynamics (e.g., learning by doing with strong internal economies would imply that firms set price based on current and future costs) since pricing here is period-by-period. We do not address dynamics due to the lack of cost data, so these markups could be overstated, especially in the years following the introduction of a new product.[10] Benkard (2000a) simulates a dynamic model of the aircraft industry assuming that firms compete in quantities. It is difficult to make direct comparisons between his results and ours because he simplifies the industry's structure and product varieties to reduce the computational burden of dynamic simulations. Nevertheless, his model performs much better than ours at predicting the aircraft cost and markups right after the introduction of the aircraft. This is especially the case for the L-1011 (or the type of plane that resembles L-

[10] Because of the lack of information we also cannot address the cost-side of aircraft industry well (e.g., learning, static economies of scale, etc.). Using detailed data on labor inputs for L-1011, Benkard (2000b) suggests that learning effects seem to matter initially in the production process, but are not a key factor later on: for most years, learning effects are small in relation to the production run. He shows that learning is effectively exhausted once L-1011 production reaches about 80 aircraft. Most Boeing aircraft sell at least this many products within two or three years after introduction (the Boeing 777 took 4 years to reach that level), while most Airbus aircraft reach this figure within the first 4 to 5 years after the initial launch. In the unreported regressions we have also explored the importance of static increasing returns to scale by regressing the log estimate of marginal cost implied by (4) on the log of output (controlling for various cost shifters,...). The point estimate of the coefficient on output ranged was about -.1, suggesting static increasing returns to scale.

1011 in his simulations), whose actual markup margin over price is essentially zero or negative throughout its lifespan. Benkard's simulated markup matches the observed markup well. In contrast, our estimate of the L-1011 markup over price is on the order of .5 to .6. Since we focus on the static equilibrium, our markup estimates can never fall below zero. Although Benkard does not report the simulated markups for other plane types (he imputes the L-1011 costs to other aircraft), the graphs of his simulated prices and costs suggest that many other aircraft in the industry simulation actually have positive markups during most of their lifespan (except for the first 2-3 years). This is consistent with what we find using a static model. Also, our declining markups over time are consistent with increasing competition and Airbus's entry into this market segment.

In sum, our structural estimates capture several important features of the aircraft industry that we incorporate in our study of the trade disputes in the next section. In particular, our demand estimates suggest significant segmentation within the wide-body aircraft market, which is consistent with the anecdotal evidence on the near monopoly power enjoyed until early 1990s by the Boeing 747 in the long-range market. While the levels of our markup estimates following the first introduction of a product should be taken with caution, ignoring the dynamics might not be problematic after that time. The markup estimates suggest that competition in the wide-body aircraft market is increasing over time. We also find that, over time, the estimates of markups become relatively insensitive to the assumption of different modes of competition among the firms (Bertrand vs. Cournot). However, since Airbus and Boeing expand their products over time, the markup estimates become increasingly sensitive to accounting for multi-product firm profit maximization. These industry characteristics have not been noted in the previous studies of the industry.

3. Aspects of Airbus Competition

The results from the previous section lend some new insight into the structure of demand and competition in the wide-body aircraft market. The structural estimates, however, can be used to explore additional issues that are commonly raised in considering this market. In particular, we examine the impact of two important events: (1) the 1992 agreement between the United States and European Community regarding subsidies and competition in the aircraft production, and (2) the entry of the A-380, Airbus's new wide body that aims to compete directly with the Boeing 747.

3.1 Impact of the 1992 Agreement

Following the trade tensions between the United States and the European Union surrounding the subsidized entry of the A-300 in the early 1970s, the rivalry between Boeing and Airbus intensified considerably after Airbus introduced the narrow-body A-320 in the mid-1980s. After Air India cancelled an order for Boeing 757s when Airbus offered steep discounts on the A-320, the U.S. government intervened on Boeing's behalf. The United States threatened using the countervailing duty laws or opening a Section 301 case against Airbus unless an agreement on subsidies was reached. In 1992, the United States and European Community reached a bilateral agreement on trade in civil aircraft (see Tyson 1992). The agreement establishes limits on the direct and indirect (military) subsidies used to finance the development of new aircraft. The maximum allowed direct subsidy is 33 percent of development costs. The agreement prohibits production subsidies. The agreement also requires detailed reporting on subsidies, interest rates, and repayment conditions, and establishes procedures to monitor the agreement.

The unanswered question is whether the 1992 bilateral agreement had any impact on pricing in the aircraft market. The one provision that could potentially affect the pricing of aircraft is the repayment provision. This provision requires that Airbus make repayments on a per-plane basis rather than delay repayment until the end of the loan. This provision reduces the risk that Airbus can significantly cut price to capture certain sales, but it does not guarantee this result.

Although we can never truly identify the effect of the 1992 U.S.-E.U. agreement on aircraft prices, our data enable use to compare the aircraft prices before and after the agreement. We thus regress aircraft prices (in logs) on a dummy variable set at unity from 1992 and other potential determinants of price. We allow the treaty to have a differential impact on Airbus's pricing by interacting the treaty indicator with the Airbus indicator. We control for other time-varying factors that could affect the pricing of aircraft through the inclusion of GDP growth, price of petroleum, market segment Herfindahl index, and a time trend. Product fixed effects control for the differences in characteristics across aircraft that affect pricing.[11] Since the estimated coefficients are not statistically different from each other when we estimate the separate narrow-body and wide-body market segment separately, we pool the data from both market segments to gain efficiency. We restrict our analysis to data from 1985 onwards so that we have equal number of time periods before and after the treaty. All regressions are estimated using product fixed effects.

Table 4a contains the results. The coefficients on the treaty indicator in various columns suggests that prices of aircraft have on average increased after the 1992 U.S. – E.U. trade agreement. The estimates range from 8.8 to 3.1 percent as we add controls for other time-

[11] The characteristics of most planes do not vary during this period. Thus, aircraft fixed effects accounts for them. In unreported regressions, we have also experimented with inclusion of plane characteristics in random effects regressions. They yield similar findings.

varying factors that could independently affect prices such as market concentration captured by Herfindahl index (column 1), GDP growth and price of petroleum (column 2), a time trend (column 3), and all of the above controls (column 4).[12] Moreover, our results suggest that the agreement did not have a differential impact on the pricing of Airbus. The coefficient on the interaction of treaty and Airbus is always insignificant. Overall, our evidence suggests that the 1992 U.S.-E.U. agreement limiting aircraft subsidies appears to have raised prices of Boeing and Airbus aircraft. This behavior is consistent with a Cournot or a Bertrand duopoly model in which subsidies are eliminated. Given that no publicly available data exist on the magnitude of the subsidy reductions, it is difficult to judge whether these price increases are big or small. However, the structural model and estimates for the wide-body aircraft from section 2 enable us to check how big of subsidy reductions these price increases potentially imply. In particular, we use the estimates of demand parameters, marginal costs c implied by Bertrand pricing equilibrium, predicted market share equation (1), and equilibrium pricing equation (4) to simulate equilibrium prices under various increases in firms' marginal costs (i.e. various reductions in subsidies). We consider firms' marginal cost increases ranging from 5 to 20 percent. Table 4b reports the average prices of wide-body aircraft under each of the scenarios and the average percent increase in prices (relative to the baseline of no change in marginal cost). The table suggests that the observed average 3 to 6.6 percent price increases correspond to about 7.5 to 12.5 percent increase in the marginal costs of firms.

[12] Some planes exit the market before 1992 and some planes enter the market after 1992. Their effect on the competition is captured through the Herfindahl index. Also, since we rely on the product fixed effects, the coefficient on the treaty indicator is identified by the price variation for the products that were in the market before and after the agreement.

3.2 Impact of A-380 Entry

The most recent trade controversy has centered on government funding for Airbus's super-jumbo aircraft, the A-380, whose first deliveries are expected in the year 2006. As Figure 1 indicates, the A-380 will be the world's largest passenger aircraft, designed to carry between 550 to 650 people, have a range of over 14,200 km (8,000 miles), and have a takeoff payload of 540,000 kg. The governments of France, Germany, and the United Kingdom are expected to cover about one-third of the estimated $12 billion in development costs. The United States has warned the European governments that the Airbus financing may violate the 1992 agreement and subsidy rules established in the World Trade Organization in 1994. The EU has countered by asking that indirect subsidies to Boeing from military and NASA contracts be examined.

Press reports indicate that the list price of the A-380 is $235 million, but also suggest that discounts on the order of at least 10 percent are being negotiated with potential buyers. Some reports even indicate that 35 percent discounts have been offered, but the industry observers believe such large discounts will not last for long. Airbus has indicated that 250 aircraft must be sold for it to break even and cover the enormous development costs. Airbus has only decided to go ahead with the production once the advanced orders hit the 50-plane mark, and about 60 planes have been ordered (as of early 2001). The A-380 is designed to compete directly against the Boeing 747 at the high end of the wide-body market. Airbus claims that due to the operating-cost effectiveness of the A-380 (relative to Boeing 747), the airlines flying the A-380 need to fill only 33 additional passenger seats to break even (relative to Boeing 747 break-even passenger requirement). Boeing denies that there is a profitable market for such "super jumbos" and is planning on producing modified versions of the 747 to compete against the A-380.

Given the heated trade debate and controversy surrounding the A-380 entry, we simulate the impact of the entry on the prices and market share of existing aircraft using our structural parameter estimates and product characteristics from section 2. We first follow the methodology in Bresnahan, Stern, and Trajtenberg (1996) and consider the impact of the new product on the market shares of exiting planes, not allowing for changes in prices and other plane characteristics. Using the estimates of the demand parameters and the information on the A-380 attributes, we first predict the A-380 mean utility level δ.[13] We then use the market share equation (1) and calculate the predicted market share for the A-380, the outside good, and all existing wide-body products before and after the entry.[14] We simulate the annual post entry market when the A-380 is sold at the list price, at a 10 percent discount, at a 20 percent discount, and at a 30 percent discount.

The results are presented in Table 5. The top part of the table reports overall market share and the percentage changes in market share under different scenarios relative to the no entry case. The bottom part of the table reports the aircraft market share within a market segment (and respective percentage change in market share relative to the no entry case) under different scenarios. Given that the press releases suggest significant initial price discounts on the A-380, we focus on the results when the A-380 is sold at a 20 percent discount. The A-380 gains 2.3 percent of the overall annual market (which translates into 18 aircraft), and 9.4 percent of the market within the long-range market segment. Boeing 747, for example, controls 6.7 percent of the overall market prior to the A-380 entry (28.5 percent of the long-range market segment). The simulation results reflect the importance of market segmentation within the wide-body market. As a result of A-380 entry, the overall market share of each long-range wide body aircraft (for

[13] The A-380 list price is adjusted to 1995 dollars so that they are comparable with the rest of our data. We assume that its unobserved quality equals the unobserved quality of A-340.
[14] We use product characteristics and total market size from the last year of our data 1998.

example Boeing 747) declines by 5.3 percent, while the overall market share of each medium-range plane (for example Boeing 767) declines only by 1.4 percent. This translates into the total annual loss of 10 sales by the existing long-range varieties and the total annual loss of 1 sale by the existing medium-range wide body varieties. Moreover, the comparison of the results across various pricing options for the A-380 reveals the importance of price discounts in securing a higher market share for the A-380. While Airbus is only able to sell 4 A-380s per year at the list price (corresponding to 0.6 percent market share), the annual sales of the A-380 increase to 35 planes at a 30 percent discount (4.5 percent market share). Our results thus seem to be consistent with the reports that cumulative orders for the A-380 are now around 60 planes and that some of these aircraft have been sold at significant discounts.

These calculations could overstate the impact of the A-380 entry on the demand for existing models because we assume that the prices of those products do not respond to entry. Therefore, we also perform simulations in which we allow the existing planes to respond to the A-380 entry by changing prices. We proceed as follows. First, we take the A-380 announced prices and characteristics as given. Using the estimates of the demand parameters and the information on the A-380 attributes we predict the A-380 mean utility level δ. We incorporate the A-380 mean utility level δ in the predicted market share expression (1) for each of the existing products and the outside good. Third, using this "augmented" predicted market share equations (1) and the pricing equation (4), we simulate the new equilibrium prices and market shares for each of the existing products. We simulate the annual post entry market when the A-380 is sold at the list price, at a 10 percent discount, at a 20 percent discount, and at a 30 percent discount.

Table 6 presents these results. The no entry case always serves as the comparison group. Since the A-380 rivals can adjust their prices, the predicted market share of the A-380 is about 0.1 to 1.5 percentage points lower than in the respective scenarios in table 5. In the case where the A-380 is sold at a 20 percent discount, it gains 2.2 percent of the overall market (17 planes) and 8.9 percent of the long-range wide-body market. The market share loss is the biggest for Airbus's own products, especially in the long-range market segment since their prices do not fall as much following the A-380 entry. The A-380 substantially undercuts the demand for the A-330 and A-340, which illustrates the risk that multi-product firms face in introducing new models. Nevertheless, the overall market share of Airbus still increases.

Prices of Boeing aircraft fall from 0.6 to 2.2 percent. As a result, their market share losses are smaller than in table 5. For example, since 747 lowers its price by 1.5 percent, its overall market share declines by 1.1 percent and by 7.6 percent in the long-range market segment. Overall, given that the industry sources indicate that the Boeing 747 accounts for a substantial portion of Boeing's profits, the subsidized A-380 entry into the market might have a significant negative impact on the U.S. producer and lead to future conflicts in U.S.-E.U. trade relations.

3. Conclusions

This paper has taken an empirical look at international competition and trade disputes in the wide-body aircraft market. Given that the aircraft industry continues to be the source of trade friction between the United States and the European Union, our main goal was to evaluate two key trade issues. We find evidence that is consistent with the 1992 U.S. – E.U. agreement to limit subsidies resulting in higher aircraft prices. Although we cannot say anything about the magnitude of the government development subsidies that have helped aircraft producers to launch their products, our evaluation of the 1992 agreement suggests the observed price increases after the agreement are consistent with increases in firms' marginal costs by about 7.5 percent. We also predict that the introduction of the Airbus A-380 will substitute most strongly for existing Airbus aircraft rather than the Boeing 747, although the negative impact on demand for the 747 is not negligible. The extent of this substitution depends critically on the price discounts that Airbus offers on the A-380.

To reach these conclusions, the paper estimated the demand for wide-body aircraft and firm markups under various assumptions on the mode of competition. This exercise yields several insights into the wide-body aircraft market. First, we find evidence of significant market segmentation between the medium-range and long-range wide body planes, which is important in evaluating the impact of the new Airbus A-380 entry. This market segmentation is also consistent with the market dominance of the Boeing 747 during the past 20 years. Second, our estimates of demand elasticities and markups suggest increased market competition despite the small number of firms. Third, the markup estimates implied by the Bertrand and Cournot competition become increasingly similar over time. This might be explained by the growing presence of multi-product firms in the industry. As producers expand the range of products, their incentive to aggressively underbid their rivals is diminished, since price cuts might also hurt their own sales of other products. Thus, the distinction between Bertrand and Cournot competition becomes less clear.

This industry feature might have some implications for the literature on the strategic trade policy. Theory models such as Bradner and Spencer (1985) and Eaton and Grossman (1986) have shown that the optimal trade policy to shift profits across countries is sensitive to whether the firms compete in prices or quantities.[15] These models have focused on single-product firms. Our results suggest that the existence of multi-product firms makes the Bertrand behavior less aggressive and this distinction less clear. Moreover, the presence of multi-product firms makes it more challenging for the aircraft companies to successfully introduce new aircraft without hurting their existing product line. This is demonstrated in our simulations of the A-380 entry into the market. We predict that the entry will lower the market share of Airbus's existing long-range wide-bodies by more than the market share of Boeing 747.

Nevertheless, many questions remain unanswered. In producing a more thorough treatment of aircraft demand and substitution patterns across aircraft than previous work, we have been constrained to say little about the production-side of the aircraft market, in particular, the impact of economies of scale and scope on profits and competition in the market. A full model of the industry would include a detailed econometric analysis of the cost and production side as well as demand. Benkard (2000b) provides a first step in this direction. Moreover, because our model is static, we also cannot address the issues of strategic trade policy that are more dynamic in nature such as the role of government subsidies to promote the aircraft market entry.

[15] Maggi (1996) presents a model in which firms' mode of competition is determined endogenously by the importance of capacity constraints and studies the implications of strategic trade policy in that context.

Data Appendix

We take our data on annual aircraft deliveries and average sales price from 1969 to 1998 from the industry publication The Airline Monitor (May 1999 issue). Aircraft characteristics, such as passengers, range, take-off weight, typical number of seats were taken from various issues of Jane's World Aircraft. Summary statistics on data are provided in Table 1 for wide-body and narrow-body aircraft. Data on A-380 characteristics was obtained from the Airbus Industrie web site (http://www.airbus.com/pdfs/A380/BRIEF2000.pdf).

Data on producer price indices, exchange rates, price of petroleum, GDP growth, and the price of aluminum are taken from IMF's International Financial Statistics Yearbook. Data on the U.S. hourly manufacturing wages and the U.S. producer price index is from the Bureau of Labor Statistics (online data). Data on hourly manufacturing wages for France, Germany (the states comprising former West Germany), and Great Britain are from the Yearbook of Labor Statistics published by the International Labor Organization. We computed a weighted average of hourly manufacturing wages in France (weight is .4), Germany (weight is .4), and Great Britain (weight is .2) using weights that mimic the individual country's ownership shares in the Airbus Consortium. Similar procedure was used to compute the producer price index for Airbus. All values are expressed in 1995 U.S. dollars.

Appendix 1—Cournot Equilibrium

When the firms compete in quantities, the first order conditions for profit maximizing firm f with respect to product j yield:

$$\sum_{k \in F_f} \frac{dp_k}{ds_j} * s_k + (p_j - \frac{\partial C_j}{\partial s_j}) = 0$$

To derive a pricing equation for each product j, we use vector notation. Let p denote a Jx1 price vector, c a Jx1 vector of marginal costs, and s a Jx1 vector of market shares of all products offered at time t (time subscript is omitted in the notation). Let Ω^c be a JxJ matrix whose element in row k and column j equals $-\frac{\partial p_j}{\partial s_k}$ if aircraft j and k are produced by the same firm and 0 otherwise. We can then rewrite the first order profit maximizing conditions in vector form as:

$$p = c + \Omega^c s .$$

We still need to find the expression for $\frac{\partial p_j}{\partial s_k}$. As discussed in section 2.1, Berry (1994) shows that one can invert the predicted market share function for product j (1) to obtain an analytic expression for the mean utility level of product j δ_j as a function of product market share and distributional parameter σ:

$$\delta_j(S, \sigma) = \ln S_j - \sigma \ln S_{j|g} - \ln S_o .$$

Moreover, remember that the mean utility level of product j is defined as $\delta_j \equiv x_j \beta - \alpha p_j + \xi_j$.

Thus:

$$\frac{\partial p_j}{\partial s_j} = \frac{\partial p_j}{\partial \delta_j} \frac{\partial \delta_j}{\partial s_j} = \frac{1}{\alpha} (\frac{1}{s_j} - \frac{\sigma}{s_j} + \frac{\sigma}{s_g} + \frac{1}{s_o})$$

where s_g is the market share of the market segment g in the overall market and s_o is the market share of the outside good.

Similarly,

$$\frac{\partial p_j}{\partial s_k} = \frac{\partial p_j}{\partial \delta_j}\frac{\partial \delta_j}{\partial \delta_k}\frac{\partial \delta_k}{\partial s_k} = \frac{1}{\alpha}\frac{\partial \delta_j}{\partial \delta_k}\left(\frac{1}{s_k} - \frac{\sigma}{s_k} + \frac{\sigma}{s_g} + \frac{1}{s_o}\right).$$

We still need to obtain $\frac{\partial \delta_j}{\partial \delta_k}$ in the above expression. By implicit function theorem:

$\frac{\partial \delta_j}{\partial \delta_k} = -\frac{\frac{\partial s_j}{\partial \delta_k}}{\frac{\partial s_j}{\partial \delta_j}}$. Differentiating (1) with respect to mean utility of product j and k thus yields:

$$\frac{\partial \delta_j}{\partial \delta_k} = \begin{cases} \dfrac{s_k\left(\frac{\sigma}{(1-\sigma)} s_g^{-1} + 1\right)}{\frac{1}{(1-\sigma)} - s_j\left(\frac{\sigma}{(1-\sigma)} s_g^{-1} + 1\right)} & if \quad j,k \in g \\ \dfrac{s_k}{\frac{1}{(1-\sigma)} - s_j\left(\frac{\sigma}{(1-\sigma)} s_g^{-1} + 1\right)} & if \quad j \in g, k \notin g. \end{cases}$$

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Figure 1—Range and Typical Number of Seats for Wide Body and Narrow Body Aircraft

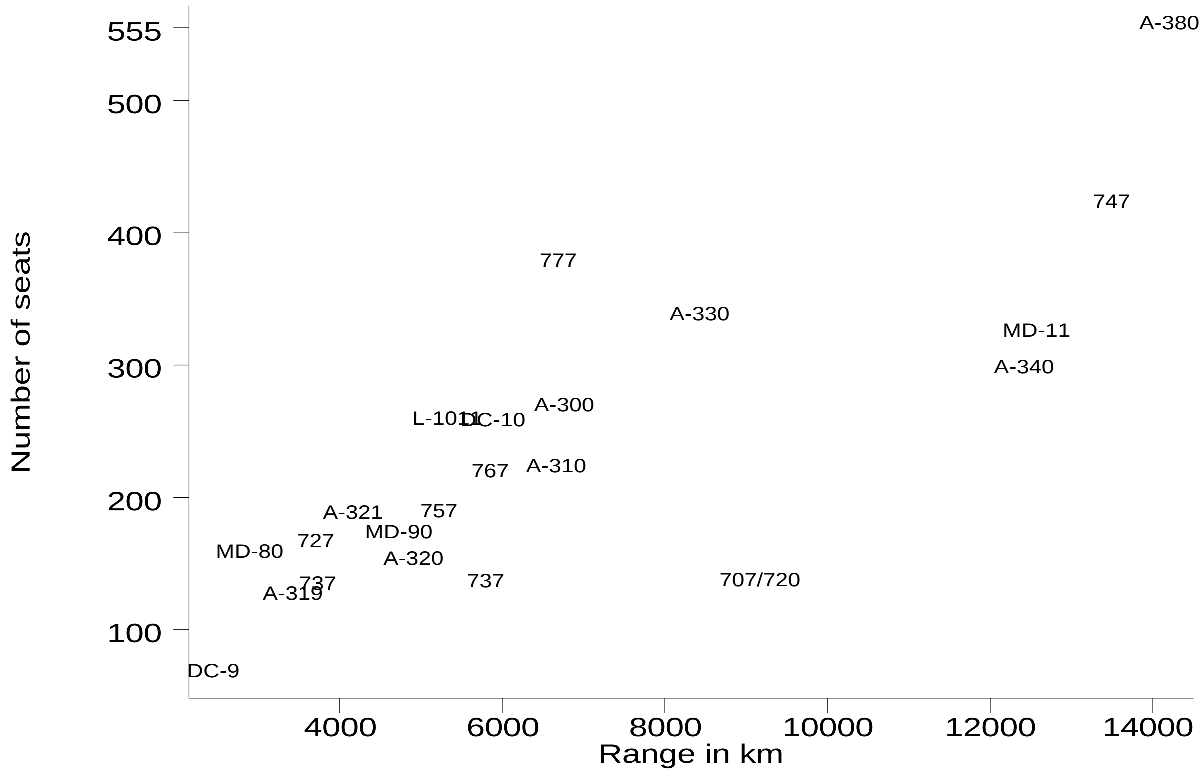

Table 1--Descriptive Statistics

Variable	Number of plane-years	Mean	S.D.
Wide-body aircraft			
Price (million 1995 $)	148	80	26
Quantity Sold	148	26	18
Market Share	148	.069	.054
Take off weight (kg)	148	224,798	76,948
Typical number of seats	148	293	67
Range (km)	148	8,038	2,683
Narrow-body aircraft			
Price (million 1995 $)	141	29	10
Quantity Sold	141	58	46
Market Share	141	.141	.098
Take off weight (kg)	141	74,390	27,000
Typical number of seats	141	143	37
Range (km)	141	4,456	2,184

Note: Data from 1969-1998. Market share refers to product's market share in the combined narrow-body and wide-body market.

Table 2--Estimates of Demand Equation

	OLS		FIXED EFFECTS		IV		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
price	-0.0146 *	-0.0033	-0.0420 **	-0.0224 **	-0.0207 **	-0.0184	-0.0195 **
	(0.008)	(0.006)	(0.012)	(0.005)	(0.011)	(0.018)	(0.010)
take off weight	-0.000001	-0.000002	-0.003099	-0.001189	-0.000003	-0.000002	-0.000003
	(0.000004)	(0.000002)	(0.001492)	(0.000807)	(0.000002)	(0.000003)	(0.000002)
number of seats	0.0067	0.0007	-3.8817	-1.6789	0.0068	0.0068	0.0064
	(0.004)	(0.002)	(2.098)	(1.182)	(0.005)	(0.008)	(0.004)
range	0.00004	0.00003	0.06051	0.02454	0.00010	0.00008	0.00010
	(0.00007)	(0.00003)	(0.03045)	(0.01693)	(0.00006)	(0.00007)	(0.00005)
gdp growth	0.0531	0.0075	0.0546	0.0323	0.0260	0.0373	0.0251
	(0.063)	(0.036)	(0.060)	(0.027)	(0.048)	(0.066)	(0.046)
petroleum price	0.0113	0.0092	0.0070	0.0067	0.0069	0.0086	0.0071
	(0.009)	(0.006)	(0.008)	(0.005)	(0.007)	(0.008)	(0.007)
σ	n.a.	0.8759 **	n.a.	0.9539 **	0.3830 **	0.2204	0.4102 **
		(0.045)		(0.058)	(0.173)	(0.715)	(0.165)
Instrument set					rival products' attributes	cost shifters	all
P-value from overidentification test					.114	n.a.	.074
Adjusted R2	.084	.736	.264	.818	.513	.365	.539

Note: Huber-White standard errors are reported in parenthesis. ** indicates significance at a 5 and 10% level, respecitively for thecoefficient on price and sigma. Number of observations is 148. Fixed effects refer to product fixed effects. Rival products' attributes includes the average number of seats, the average take off weight, and the average range taken over the competitors a product faces in its market segment and the wide-body market overall (excluding the product in question). Cost shifters include hourly manufacturing wages and price of aluminum. The reported p-value is from the F-test whether the coefficients are jointly insignificant in a regression of 2SLS residuals on instruments and explanatory variables.

Table 3--Estimates of Price Elasticities and Markups (Period averages)

Period	Price Elasticities			Markup Margin (p-c)/p				
	(1) Own price	(2) Cross price same segment	(3) Cross price across segments	(4) Single-product Bertrand	(5) Multi-product Bertrand	(6) ((5)-(4))/(4)	(7) Multi-product Cournot	(8) ((8)-(5))/(5)
1969-1973	-1.158	0.907	0.206	0.899	0.899	0.000	1.022	0.146
	(0.239)	(0.372)	(0.137)	(0.192)	(0.192)	(0.000)	(0.210)	(0.139)
1974-1978	-1.430	0.552	0.099	0.711	0.711	0.000	0.800	0.123
	(0.201)	(0.421)	(0.052)	(0.090)	(0.090)	(0.000)	(0.125)	(0.070)
1979-1983	-1.564	0.549	0.110	0.651	0.671	0.032	0.763	0.130
	(0.218)	(0.534)	(0.080)	(0.091)	(0.099)	(0.058)	(0.148)	(0.067)
1984-1988	-1.877	0.553	0.083	0.550	0.611	0.107	0.670	0.086
	(0.330)	(0.633)	(0.058)	(0.100)	(0.135)	(0.092)	(0.182)	(0.059)
1989-1993	-2.482	0.536	0.092	0.428	0.494	0.175	0.536	0.084
	(0.632)	(0.516)	(0.079)	(0.106)	(0.113)	(0.226)	(0.130)	(0.056)
1994-1998	-2.837	0.435	0.099	0.379	0.455	0.216	0.491	0.083
	(0.722)	(0.297)	(0.069)	(0.112)	(0.128)	(0.184)	(0.134)	(0.056)
1969-1998	-2.095	0.542	0.103	0.541	0.589	0.116	0.651	0.101
	(0.773)	(0.479)	(0.079)	(0.189)	(0.176)	(0.167)	(0.213)	(0.071)

Note: The reported elasticities are period averages. Standard deviations are reported in parenthesis.

Table 4a--The Impact of the 1992 U.S.-E.U. Agreement on the Pricing of Aircraft

	(1)	(2)	(3)	(4)
treaty	0.0880 **	0.0323 **	0.0665 **	0.0305 *
	(0.015)	(0.016)	(0.016)	(0.017)
treaty*airbus	0.019	0.018	0.024	0.020
	(0.020)	(0.018)	(0.019)	(0.018)
herfindahl index	-0.217	0.211	-0.267	0.151
	(0.142)	(0.146)	(0.139)	(0.157)
gdp growth			-0.001	0.000
			(0.005)	(0.005)
price of petroleum			-0.004	-0.001
			(0.001)	(0.001)
time trend		0.013		0.012
		(0.002)		(0.002)
N	160	160	160	160

Note: ** indicates significance at a 5 and 10% level, respecitively for the coefficient on the treaty indicator and the treaty*airbus. Dependant variable is ln price. All regressions are estimated using product fixed effects. This regression includes wide-body and narrow-body aircraft.

Table 4b--The simulated effect of the 1992 trade agreement on prices

Marginal cost increase	No change	5%	7.5%	10%	12.5%	15%	17.5%	20%
Average Price	89.6	91.9	93.0	94.1	95.3	96.4	97.6	98.7
Standard Deviation	(27.1)	(28.2)	(28.8)	(29.3)	(29.9)	(30.4)	(31.0)	(31.6)
Avg. % Change in Price	n.a.	2.43	3.64	4.86	6.08	7.31	8.53	9.76
Standard Deviation	n.a.	(.60)	(.90)	(1.20)	(1.50)	(1.80)	(2.10)	(2.40)

Note: Simulations are based on demand parameter estimates from table 2, column 7 and the assumption of Bertrand pricing. Simulations use aircraft characteristics and marginal cost estimates from 1992. The prices are expressed in million 1995$.

Table 5--The effect of A380 entry on existing aircraft when prices do not respond to new entry

	No entry	List price		10% discount		20% discount		30% discount	
	actual	simulated	% change	simulated	% change	simulated	% change	simulated	% change
Market Share									
Long Range									
A380		.006		.012		.023		.045	
747	.0673	.0664	-1.3	.0655	-2.7	.0637	-5.3	.0604	-10.1
777	.0939	.0927	-1.3	.0914	-2.7	.0889	-5.3	.0844	-10.1
MD11	.0152	.0150	-1.3	.0148	-2.7	.0144	-5.3	.0137	-10.1
A330	.0292	.0288	-1.3	.0284	-2.7	.0276	-5.3	.0262	-10.1
A340	.0305	.0301	-1.3	.0296	-2.7	.0288	-5.3	.0274	-10.1
Medium Range									
767	.0596	.0594	-0.3	.0592	-0.7	.0588	-1.4	.0580	-2.8
A300	.0165	.0164	-0.3	.0164	-0.7	.0163	-1.4	.0160	-2.8
A310	.0013	.0013	-0.3	.0013	-0.7	.0013	-1.4	.0012	-2.8
Outside good	.6865	.6842	-0.3	.6818	-0.7	.6770	-1.4	.6676	-2.8
Market share within each wide-body market segment									
Long Range									
A380		.024		.048		.094		.175	
747	.285	.278	-2.4	.271	-4.8	.258	-9.4	.235	-17.5
777	.398	.388	-2.4	.379	-4.8	.361	-9.4	.328	-17.5
MD11	.065	.063	-2.4	.061	-4.8	.059	-9.4	.053	-17.5
A330	.124	.121	-2.4	.118	-4.8	.112	-9.4	.102	-17.5
A340	.129	.126	-2.4	.123	-4.8	.117	-9.4	.106	-17.5
Medium Range									
767	.771	.771	0.0	.771	0.0	.771	0.0	.771	0.0
A300	.213	.213	0.0	.213	0.0	.213	0.0	.213	0.0
A310	.016	.016	0.0	.016	0.0	.016	0.0	.016	0.0
Number of A-380 sold		4.5		9.1		18.2		35.5	
Decline in sales of LR aircraft		2.4		4.9		9.8		18.9	
Decline in sales of MR aircraft		0.2		0.4		0.8		1.7	
Decline in sales of outside good		1.8		3.7		7.5		14.9	

Note: Simulations are based on demand parameter estimates from table 2, column 7. The reported percentage changes are relative to the simulated market share with no A380 entry reported in the first column. Simulations use aircraft characteristics from the last year of the data (1998). The changes in sales are calculated based on the 1998 market size (788 planes).

Table 6--The effect of A380 entry on existing wide body planes

	No entry	List price		10% discount		20% discount		30% discount	
	actual	simulated	% change	simulated	% change	simulated	% change	simulated	% change
Market Share									
Long Range									
A380		.006		.011		.022		.043	
747	.0673	.0671	-0.2	.0669	-0.5	.0665	-1.1	.0655	-2.6
777	.0939	.0937	-0.2	.0934	-0.5	.0928	-1.1	.0915	-2.6
MD11	.0152	.0152	-0.2	.0152	-0.5	.0151	-1.1	.0148	-2.6
A330	.0292	.0287	-1.6	.0282	-3.3	.0273	-6.3	.0258	-11.6
A340	.0305	.0300	-1.6	.0295	-3.3	.0285	-6.3	.0269	-11.6
Medium Range									
767	.0596	.0594	-0.3	.0592	-0.7	.0589	-1.3	.0581	-2.5
A300	.0165	.0164	-0.6	.0163	-1.2	.0161	-2.3	.0158	-4.3
A310	.0013	.0013	-0.6	.0013	-1.2	.0012	-2.3	.0012	-4.3
Outside good	.6865	.6826	-0.6	.6787	-1.1	.6711	-2.2	.6576	-4.2
Market share within each wide-body market segment									
Long Range									
A380		.023		.046		.089		.160	
747	.285	.279	-2.0	.274	-4.0	.263	-7.6	.245	-14.0
777	.398	.390	-2.0	.382	-4.0	.368	-7.6	.342	-14.0
MD11	.065	.063	-2.0	.062	-4.0	.060	-7.6	.056	-14.0
A330	.124	.120	-3.4	.116	-6.6	.108	-12.5	.097	-21.9
A340	.129	.125	-3.4	.121	-6.6	.113	-12.5	.101	-21.9
Medium Range									
767	.771	.7709	0.1	.7713	0.1	.7722	0.2	.7737	0.4
A300	.213	.2127	-0.2	.2123	-0.4	.2115	-0.7	.2101	-1.4
A310	.016	.0164	-0.2	.0163	-0.4	.0163	-0.7	.0162	-1.4
Price (million 1995 $)									
Long Range									
747	146.8	146.2	-0.4	145.6	-0.8	144.5	-1.5	142.7	-2.7
777	107.6	107.0	-0.6	106.5	-1.1	105.4	-2.1	103.6	-3.7
MD11	101.8	101.2	-0.6	100.6	-1.2	99.5	-2.2	97.7	-4.0
A330	105.7	105.5	-0.2	105.4	-0.3	105.1	-0.6	104.6	-1.0
A340	112.8	112.6	-0.2	112.4	-0.3	112.1	-0.6	111.7	-1.0
Medium Range									
767	75.3	75.2	-0.2	75.1	-0.3	74.9	-0.6	74.5	-1.1
A300	82.6	82.5	-0.1	82.5	-0.1	82.4	-0.2	82.3	-0.3
A310	67.5	67.4	-0.1	67.4	-0.1	67.3	-0.2	67.2	-0.4
Number of A-380 sold		4.4		8.9		17.6		33.7	
Decline in sales of LR aircraft		1.1		2.2		4.5		9.0	
Decline in sales of MR aircraft		0.2		0.5		0.9		1.8	
Decline in sales of outside good		3.1		6.2		12.1		22.8	

Note: Simulations are based on demand parameter estimates from table 2, column 7. The reported percentage changes are relative to the base of no A380 entry reported in column 1. Simulations use aircraft characteristics from the last year of the data (1998). The changes in sales reported in text are calculated based on the 1998 market size (788 planes).