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## Industrial policy in the transport aircraft industry

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**INDUSTRIAL POLICY  
IN THE TRANSPORT AIRCRAFT INDUSTRY**

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✓  
November 1989

Institut für Weltwirtschaft an der Universität Kiel  
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## INTRODUCTION

Large commercial aircraft is one of the areas in which the United States accuse European governments of unfair trade practices. AIRBUS Industries is undoubtedly heavily supported by subsidies from all participating countries. From 1970 up to today at least 11-12 Billion US-\$ have been paid by European governments; some American estimates of that support come to as much as 20 Billion US-\$. The development of the A330/340 and 321 will require several billion more in the next few years. These payments were caused by the decision of European governments in the late 1960's to support market entry of an European competitor in the market for large transport aircraft.

Up to now these subsidies have been predominantly paid for the financing of start-up investments of the now existing and planned fleet of aircraft, the A300, A310, A320, A330, A340, most likely the A321, and possibly a military freighter. This situation might change in the future, because the German government has agreed to grant production subsidies under specific circumstances. By the end of 1989 Daimler-Benz will merge with MBB, the German partners of Airbus Industrie, and a precondition of Daimler-Benz for acquiring the risky commercial aircraft business was a long term exchange rate guarantee. Since aircraft is sold in US-Dollars worldwide this could amount to a production subsidy if the DM/\$ exchange rate stays at a lower level than today for a considerable time.

In this paper the impact of subsidized market entry of Airbus over the next 20 years is simulated. The welfare effects of this subsidized entry are assessed by comparing the actual allocation to an American monopoly and alternatively to an American duopoly. Then the effects of an

ad-valorem subsidy for Airbus on allocation and welfare are simulated. Finally, the impact of potential retaliation by the American administration on competition among the European and American producers is analyzed.

## INDUSTRY CHARACTERISTICS

Today there are three large producers of large transport aircraft: BOEING (over 50% market share), AIRBUS (30-35%), McDonnell Douglas (10-15%). Other civil aircraft forms a relatively minor part of the industry in terms of value. In the United States large transport aircraft covers about 70% of all civil aircraft industry shipments. Light transport aircraft, helicopters, business aircraft, and other aircraft account for the rest (U.S. Department of Commerce, 1986).

The three large producers are embedded in a network of sub-contractors which supply parts of the aircraft. Most importantly the engines amounting to 20-30% of the value of an aircraft are developed by outside companies. Avionics, systems, and components (brakes, tires etc.) are often sub-contracted as well.

The market is small in terms of number of aircraft sold, but each aircraft is an expensive product. 400 to 500 large transport aircraft are expected to be sold every year with yearly fluctuations. Aircraft prices range from \$ 25 to \$ 30 million for a Boeing 737, to \$ 30 to \$ 32 million for an A320, to around \$ 120 million for a Boeing 747. The relatively small number of aircraft sold goes hand in hand with a long product cycle. It takes 5-6 years from launch to first delivery. Then an aircraft has a product cycle of at least 20-25 years of production during which it may be upgraded to new technological standards.

Large transport aircraft have a complex production technology which results in strong learning effects. An essential part of learning appears in the assembly of an aircraft. Craftsmanship and timing of thousands of activities is required there. Such experience is embodied in the workforce and accumulates with the number of aircraft that have been produced. There is world-wide consensus that aircraft production exhibits a learning elasticity of 0.2, i.e. production cost decrease by 20% with a doubling of output (BERG/TIELKE-HOSEMANN, 1987, U.S. Department of Commerce, 1986). (See figure A1 in the appendix for some empirical examples). Whereas start-up investments and R&D are costly in absolute terms, economies of scale are dominated by the learning effect which amount to 90% of the overall economies of scale (see below). Some production stages are not specific to a particular type of aircraft, such that learning effects which are realized in the production of a generic aircraft can influence marginal cost of producing another generic aircraft. Such cross effects are strong for updated versions of an aircraft, the so-called "derivatives". These effects can be captured by economies of scope.

Industry characteristics can then be summarized under

- static economies of scale (R&D and start-up investment)
- dynamic economies of scale (learning in production)
- economies of scope (cross effects of learning).

## COMPETITION

Aircraft producers compete in essentially two ways. There is first the long-run decision about product choice and capacity. The demand in each segment even over a long time horizon is small in terms of the number of aircraft. 3000 to

4000 units each in the short and medium range market and around 2000 units in the long-range market are the expected market size over the next 20 years. Since learning effects are embodied in the work force, capacity choice becomes the crucial long-run decision variable.

There is, of course, limited information about future demand. Market forecasts by the large producers over the next 20 years, however, do not differ greatly suggesting that the game is played under identical expectations. Figure A2 in the appendix illustrates the different types of aircraft which are currently offered by the three producers according to range and seating capacity. In each of the market segment - short range narrow-bodied, short and medium range wide-bodied, and long-range aircraft - Airbus and Boeing offer competing generic aircraft with possibly a number of derivatives.

Once capacity is determined, aircraft producers have limited choice over short-run output levels. They bargain with airlines in their day-to-day marketing activities over the price of aircraft. Airlines seem to make extensive use of repeated negotiations with the suppliers of an aircraft for a specific market segment. Competition takes the form of a price game at given capacity levels, where the outcome of the long-run quantity game then becomes a restriction in the short-run price game. If demand turns out to be larger than expected, firms will produce at their capacity limit and choose prices which maximize profits. For unexpectedly low demand the price game may drive prices down to marginal cost levels. In extreme cases so-called "white tails" are produced, i.e. aircraft are produced without a customer in sight.

## MARKET ENTRY

Entry in a market such as that for large transport aircraft is an expensive and time consuming effort. Dynamic and static economies of scale together with economies of scope give incumbent firms a considerable competitive advantage. It is therefore not surprising that market entry of AIRBUS was accompanied by heavy involvement of European governments. After several commercially unsuccessful projects European aircraft producers were not willing to take the risks of yet another gamble.

When in the 1960's European aerospace firms were considering to enter the market for large transport with a new generation of aircraft, this market was almost completely dominated by the three American producers - Boeing, McDonnell Douglas, and Lockheed. Previously produced European aircraft was not successful commercially and the outlook was that no non-American producer could compete in size with the three firms. In this situation market entry can be viewed as the first of a three stage decision process. First, the commitment of European governments to subsidize the launch of a new aircraft was necessary since apparently financing on capital markets without state support was not possible. Secondly, firms had to decide which market segment to enter and they had to choose a capacity which allowed them to capture the learning effects of large scale production and at the same time kept prices at a profitable level. Finally, once the two decisions are made they had to compete with the other producers in the day-to-day business of selling their product.

The first decision must be made under great uncertainty and not only economic but also political arguments govern this process. Industrial policy aspects such as the civil-military interaction in the aerospace industry were important.

From the perspective of European firms government support turned out to be essential. Not only the financial burden for the launch of a completely new aircraft is high, but the commitment of governments to support market entry could also prevent incumbent firms from starting a price war in the hope of stripping the entrant of its financial resources (BRANDER/SPENCER, 1983). When in the "Bonner Protokoll" of September 1967 the British, French, and German governments gave their support to the launch of the A300, the first stage decision was expected to be finished.

Once the A300 came to the market in 1974 airlines were not enthusiastic about buying a new aircraft from a new producer. Parts, maintenance, training etc. did not fit the products of Boeing, Lockheed, or McDonnell Douglas. The A300 was designed to close the "window" for a high capacity short to medium range transport aircraft. While this window surely existed, the market opportunities in this segment were unclear. Lockheed and McDonnell Douglas were already engaged in head-to-head competition with their L1011 and DC-10. Their low prices could make their aircraft competitive even in the shorter range market segment of the A300. It became clear that Airbus had to supply a complete family of aircraft in order to stay in the market in the long-run. This also meant a new commitment of the participating governments to finance the new types of aircraft, since the A300 and later the A310 were not even close to their break-even point.

The political decision in the 1960's to support a European civil aircraft industry by subsidizing the development of one new aircraft, the A300, has over time turned into the need to subsidize the market entry of a producer of a complete family of aircraft. Subsidies and guarantees are given today for the development and launch of the A330 and the A340. But this is not necessarily the last step. Airbus is

not yet a producer which has internalized learning and scale effects in the same way as the established producers. The cost disadvantage of later market entry still exists. It competes in market segments in which Boeing has already realized large learning effects and is able to produce at lower marginal cost.

Such a situation invites governments not only to support market entry, but to subsidize the domestic firm in order to capture rents from the foreign firm. BRANDER/SPENCER (1985) have shown that in a Cournot-Nash game subsidies paid by one government to its domestic producer increases profits and welfare. The question arises what Europe could gain by not only supporting market entry but also by subsidizing production of its domestic producer. Up to now such subsidies have not been paid in significant amounts, but their potential impact will also be simulated.

## THE MODEL

For the purpose of this paper the political decision to support market entry is taken as given. Up to now this support has taken the form of financing the launch-investment. Such fixed cost subsidies do not affect capacity decisions of the producers. Government support, therefore, only makes credible that the entrant stays in the market even if entry is not profitable over the planning horizon. Entry deterring pricing strategies of the incumbent producer therefore are not rational. With entry so to speak "exogenously" given, the game amounts to a Cournot-Nash game in capacity over the planning horizon. The possibility that European governments will pay and may already have paid production subsidies is taken up later. Past production subsidies and marketing aid are small compared to the subsidization of the launch in-

vestment (COOPERS & LYBRAND, 1988). The amount of production subsidies to be paid in the future is unknown, since these subsidies are made dependent on the development of exchange rates.

The short-run price game naturally can not be empirically investigated, since it depends on the actual development of demand in the future. Historical examples show that aircraft prices fluctuate with demand; in the 1979-1983 rebates of up to 20% were not uncommon according to airline officials. Apart from such demand fluctuations, real aircraft prices tend to remain constant over a product cycle. The focus will be exclusively on the capacity game played between two producers which one could imagine as being Airbus Industrie and Boeing. McDonnell Douglas is left out of the model, since it has not developed a really new aircraft and seems to function more like a competitive fringe. Until the Pentagon issued a large order for military tanker aircraft recently, there had been doubts whether McDonnell Douglas would stay in the civil market at all.

The model represents a stylized picture of the industry. In particular the network of production with a large number of subcontractors is ignored. The producers are modelled as decision units and production units. This approach implicitly assumes that subcontractors have similar production technologies as the main firm. An alternative model would only investigate the value added inside the two main producers and assume that intermediate products are bought from a competitive market, a less realistic assumption.

## **SUPPLY DECISION**

Since an important part of economies of scale of aircraft production are incorporated in the learning of the workforce over time, a producer must essentially decide what the pro-

duction capacity for a particular aircraft will be. In reality this will be a sequential decision with updates as time goes on and external parameters such as demand change. Nevertheless capacity decisions do have a long-run character even if they are not made once and for all. A producer  $i$  therefore faces for a given capacity a flow of production  $y_{it}$ . The cumulative production  $x_{iT}$  at time  $T$  is then

$$(1) \quad x_{iT} = \int_0^T y_{it} \, dt.$$

Capacity choice is then equivalent to the choice of  $x_{iT}$ .

Each producer has a cost function in terms of cumulated output which incorporates learning effects, fixed cost, and economies of scope. For the purpose of this model the "CES-Cost-Function" proposed by BAUMOL ET AL. (1982) is chosen. It can incorporate all the desired features. Dropping the time subscripts the cost of producing  $k=1, \dots, m$  products for producer  $i$  are

$$(2) \quad C_i(x_i) = F_{ik} + \left[ \sum_{k=1}^m a_{ik} x_{ik}^{\beta_{ik}} \right]^{\theta_i}$$

with  $F_{ik}$  fixed cost for product  $k$

$$a_{ik}, \beta_{ik}, \theta_i > 0$$

$$x_i = (x_{i1}, \dots, x_{ik}, \dots, x_{im})$$

It is assumed that both producers have the same cost function, i.e. they are equally efficient. Since the incumbent has already realized learning effects he may be on a lower part of his learning curve thus having lower marginal cost.

The multi-product cost function  $C_i(x_i)$  has the parameter restriction  $0 < \theta_i < 1 \forall i$ , if there are economies of scope in the production of  $x$ .

In the one-product case, the cost function reduces to the classic learning curve

$$(3) \quad \frac{\delta C(x)}{\delta x} = \theta \beta a^\theta x^{\beta\theta-1}$$

with learning elasticity

$$(4) \quad \mu = \beta\theta - 1$$

All producers face the same expected inverse demand function for aircraft over the time horizon  $T$ ,

$$(5) \quad p_k = p_k(x_k, x_{-k})$$

$$\text{where } x_k = \sum_{i=1}^n x_{ik}$$

$$-k = (1, \dots, k-1, k+1, \dots, m)$$

Each producer produces in each market segment an identical product which is subject to cross price effects from other market segments. For the model simulation a linear demand representation was chosen.

The optimal capacity choice of the two producers,  $i=(A,B)$ , is found as the solution of a Cournot-Nash game with cumulated output  $x_{ik}$  as the strategic variables. The reaction functions have the familiar form. The optimal strategy of producer  $i$ ,  $(x_{i1}, \dots, x_{im})$ , is given by the  $m$  first-order conditions.

$$(6) \quad p_k \left( \sum_{j \neq i}^n x_{jk} + x_{ik}, x_{-k} \right) \left[ 1 + \frac{\hat{x}_{ik}}{\epsilon_k \sum_{k=1}^m \hat{x}_{ik}} \right] = \frac{\delta C_i(\hat{x}_i)}{\delta x_{ik}}$$

$\forall k=1, \dots, m$

with  $\epsilon_k$  = price elasticity of demand for product  $k$ .

$(x_A, x_B)$  with  $x_i = (x_{i1}, \dots, x_{im})$ ,  $(i=A, B)$ , is a Nash-Equilibrium if it satisfies equations (6) for all  $i=A, B$  and  $k=(1, \dots, m)$ .

## CALIBRATION

The effects of market entry cannot be empirically investigated with historical data since Airbus is only in the process of becoming a producer of a complete family of aircraft and none of its products have reached the end of a product cycle. The approach taken here relies on the history of production of Airbus and Boeing up to 1986 and then uses demand forecasts of the large producers up to the year 2006 as an empirical basis for the calibration of the model. This time period covers a complete product cycle for most aircraft types which are modelled here. The Airbus A330 and A340 are the exception, because they will not enter the market before 1992. Therefore demand forecasts for the long-range market will not be an entirely adequate description of the demand over the product cycle for these two aircraft types.

Demand forecasts were available for the period 1987 to the year 2000 by Boeing (Boeing Civil Aircraft Company, 1987), to 2001 by McDonnell Douglas (McDonnell Douglas, 1986), and

to 2006 by Airbus (Airbus Industrie, 1987). The McDonnell Douglas and Boeing forecasts expect an overall demand for about 5700 large transport aircraft which if projected to 2006 would predict demand to be about 8100 aircraft. The Airbus forecast is more optimistic in predicting a total market for 9797 airplanes. Although all three producer operate with differently defined market segments thus making comparisons difficult, the main difference can be attributed to a much larger Airbus prediction for the market for short to medium range wide body aircraft. In the light of recent experiences with airport congestion this trend towards larger aircraft seems realistic.

For the calibration of the model three market segments were defined: A market for short to medium range narrow-body aircraft (S), one for short to medium range wide-body aircraft (M), and one for long range wide-body aircraft (L). For the segment S the more conservative estimate was used, mainly since McDonnell Douglas' MD80's compete in this segment but are not explicitly modelled and because of the recent trend towards larger aircraft. The Airbus estimate of about 3200 aircraft for segment M was adopted. The 1750 aircraft in segment L are closer to the projected Boeing estimate than to the Airbus and McDonnell Douglas forecasts. Since the A 340 as a competitor for the Boeing 747 in the long range market segment will not enter service before 1993 this is a conservative estimate if the market over the whole product cycle is the basis for capacity decisions. In summary, the three market segments are calibrated to the following benchmarks:

$$x_S = 3500 \quad x_M = 3200 \quad x_L = 1750.$$

Listed market prices do not exist for large transport aircraft. Different customers getting different rebates, varying specifications of airplanes, and different arrangements

concerning training, spare parts, and maintenance make price documentation difficult. The prices used here are average prices derived from listed contracts (INTERAVIA) and interviews. They are modelled in constant prices and calibrated to the following approximate benchmarks:

$$P_S=27 \qquad P_M=62 \qquad P_L=100.$$

Technological characteristics are the launch investment which is taken as fix cost. For aircraft launched before 1975 an estimate of \$ 3 billion was taken (U.S. Department of Commerce, 1986). Later aircraft was assumed to have launch cost of \$ 4 billion (The Economist, 1988). Learning effects are generally believed to be strong. A learning elasticity of 0.2 is widely accepted as the correct benchmark for decreases in marginal cost. In the present model with output in the range of one to three thousand one can compute the contribution of fix cost and learning to the economies of scale directly. It turns out that launch investment accounts for only about 10% of the overall economies of scale.

Aircraft producers do not reveal marginal costs and the synergy effects among the production of different types of aircraft. Airbus officials, however claim that Airbus Industry has reached the same efficiency as their American competitors. Since no other verifiable information is available it is assumed that each producer has the same cost of producing the first airplane.

Their marginal cost may however differ widely at some point in time since their aircraft were launched at different times. Suppose two producers have the same constant production rate and the same cost function but started production at different times. The difference in marginal cost at some point in time is then given by the distance between the two

marginal cost curves. This difference becomes smaller the larger cumulative production is. With the relative small number of aircraft produced this difference is of particular importance to the aircraft industry. For the model calibration accumulated production of Boeing 737, 757, 767, and 747 and Airbus A300 and A310 in each market segment up to 1987 entered the cost function as already acquired learning effects.

Since demand for transport aircraft is derived demand, the shape of the demand curve depends on the elasticity of demand for air transport which is relatively low due to the absence of substitutes, and on the technology of producing air transport services. The price elasticity of demand for air transport seems to lie somewhere between -1.5 (KRAVIS et al., 1982) and -2.85 (commercial US domestic passenger air service; BALDWIN/KRUGMAN, 1987). The Baldwin/Krugman estimate is based on a market with larger cross price elasticities. Therefore the "true" price elasticity for world air transport will most likely be closer to the Kravis estimate. For large airlines the cost share of aircraft amounts to at most 20% of total operating cost and the elasticity of substitution between aircraft and other inputs is low. Therefore the price elasticity of demand for aircraft in general will be rather small, most likely below one.

This finding does not fit the assumed Cournot-Nash framework of a capacity game, since it requires a much larger elasticity in order to attain an equilibrium. An alternative at this point would be to give up the notion of a capacity game and to look for different models which might more adequately describe competition in the aircraft industry without violating estimated parameters. KRUGMAN/BRAINARD (1988) have tried alternative approaches, but have not made the big breakthrough yet. The other alternative is to postulate the

capacity game and to determine demand elasticities in the calibration procedure. This, of course, leads to elasticities which are higher than those theoretically derived.

In this paper the latter choice was taken, i.e. elasticities are treated as endogenous in this model. It is assumed that identical firms would earn a rate of return on turnover of about 5.5% and the demand function is accordingly calibrated to this rate of return. The resulting direct price elasticities are larger than -2 and in the long range market close to -1 which is as large as one can get in a Cournot-Nash model as it is presented here. Although a rate of return of 5,5% on turnover is rather arbitrary, the possible range of rates compatible with the model is small and the results are not sensitive to alternative values (see KLEPPER, 1990).

The parameter value for the degree of economies of scope had to be chosen arbitrarily. Its value of  $\theta = .97$  can be interpreted as follows: The introduction of a new generic aircraft when the firm has already experienced learning effects of about 1000 older and different aircraft reduces marginal cost by some 30% compared to the situation where it produces its very first airplane as e.g. in the case of the A300.

For the base case calibration of the market starting from 1987 Boeing and Airbus had already internalized learning effects in each market segment as shown in table 1. The numbers refer to Boeings 737s, 757, 767, and 747 and to Airbus' A300/310. Older aircraft like the 727 or the 707 are ignored.

Table 1: PRODUCTION UP TO 1987

	S	M	L
AIRBUS	0	288	0
BOEING	1070	149	609

Source: Interavia; current issues.

### BASE CASE RESULTS

The result of the base case calibration are summarized in table 2. Under the assumption of equal technologies for both producers output in the Nash equilibrium varies due to the cost advantages of previous learning. In market segment S Boeing's marginal cost advantage is 23% resulting in a market share of 31% for Airbus and leaving 69% for Boeing. In segment M where Airbus has a slight advantage through the early launch of the A300, a marginal cost advantage of 6% translates into a 53% market share. Similarly for segment L with cost differentials of 15% and market shares of 45% for Airbus, resp. 55% for Boeing.

Table 2: MARKET FOR LARGE TRANSPORT AIRCRAFT 1987 - 2006  
Base Case Calibration

	Market Segment					
	S		M		L	
	Airbus	Boeing	Airbus	Boeing	Airbus	Boeing
Output	1103	2430	1724	1528	796	967
Market Share	31 %	69 %	53 %	47 %	45 %	55 %
Marginal Cost	23.7	18.9	51.0	52.3	63.1	54.9
Price	27.7		62.5		101.0	

The expected profitability of the activities of the two producers can be computed either over the complete product cycle of their products, i.e. by including the sales prior to the start of the time horizon of the calibration, or for the time horizon of the calibration and before separately. The following table presents all three computations. For simplicity the prices of aircraft prior to the calibration period are set equal to the calibrated prices. This underestimates the profitability of Boeing in a period where it has a monopoly in the long range market with its 747 and also sold aircraft which is not counted here such as the 727.

Table 3: REVENUES, COSTS, AND PROFITS (\$ Billion)

	Airbus	Boeing
REVENUE		
- prior to 1987	18.0	100.5
- 1987-2006	218.8	260.6
- overall	236.8	361.1
PROFITS		
- prior to 1987	-14.7	-7.6
- 1987-2006	+11.9	+53.0
- overall	-2.8	+45.4
PROFITS/REVENUE		
- prior to 1987	-82.0 %	-7.6 %
- 1987-2006	+5.4 %	+20.3 %
- overall	-1.2 %	+12.6 %

The summary in table 3 shows how the late entry of Airbus affects profitability and production well into the next century. Airbus would have almost broken even by then, but Boeing will have a rate of return of 12.6%. For the period from 1987 to 2006 both Airbus and Boeing are profitable, if the start-up investment and high learning cost of the period to 1987 are not counted. These numbers give a rough indica-

tion of the cost disadvantage of Airbus in the 30 years after its market entry. At the end of this period the comparison is not entirely correct, since by that time in the market segments S and L Boeing will supply aircraft types which are at the end of their product cycle, whereas Airbus has aircraft in the segments S and L which are still relatively new. Therefore Boeing will during the time under investigation face development costs for a new generation of aircraft.

#### WELFARE

In order to assess the welfare consequences of government supported market entry, a fictitious market structure without this entry has to be used as a reference allocation. One can imagine two scenarios which could have become reality since 1970. If, on the one hand, the process of concentration in the aircraft industry would have continued in the 1970's as it has done in the decades before and Airbus would not have entered the market, Boeing might have eventually become a monopoly. If, on the other hand, the market is large enough for two or more producers and Lockheed or McDonnell Douglas were efficient producers, a duopoly like in the current situation might have emerged. The difference would be that the market would have two established producers instead of one new entrant and one incumbent. Both alternatives are simulated as benchmarks for the effects of alternative market structures.

Monopoly is simulated by leaving all parameters unchanged, except that there is only one producer, Boeing. Accumulated output in the monopoly situation is slightly smaller but not by a large amount. Only in the long range market segment the monopoly will supply almost 20% less aircraft. Prices rise

between 3% and 16%. Profits to the monopolist almost triple such that the rate of return over the whole product cycle increases from 12.5% in the base case to 27% in the monopoly case.

The second alternative is a duopoly with established producers of equal efficiency such that they are on the same points of their learning curves. Consequently they will share the market equally. This situation is simulated by assuming that at the beginning of the calibration period the same number of aircraft in each market segment has already been produced as in the base case. But this time the production is also shared equally by both producers. Only in the short range narrow-body market the overall output deviates significantly from the base case. This is induced by the large learning incorporated in 1070 aircraft produced prior to 1987 in the base case. Otherwise there is little deviation in the allocation from the base case.

Whereas the regional distribution of producer surplus is easy to determine, consumer surplus has to be approximated by the distribution of air-traffic. Forecasted regional market shares (AIRBUS INDUSTRIE 1987) were used to distribute consumer welfare among Europe, the United States, and the rest of the world.

Table 4 summarizes the welfare effects of Airbus market entry when it is compared to a monopoly and when compared to a duopoly. If a monopoly were the alternative market structure, market entry of Airbus could be considered successful from a consumer's point of view, but the overall welfare impact is negative. A consumer surplus gain of \$ 36.8 billion is dominated by the loss of producer surplus of \$ 110.4 billion most of which is the monopoly profit of Boeing. The regional distribution reveals welfare gains to Europe and the rest of the world, whereas in North-America, i.e. the United States, consumers gain and producers loose.

Table 4: DISTRIBUTION OF WELFARE EFFECTS OF GOVERNMENT  
SUPPORTED MARKET ENTRY (million 1986 US-\$)

	Producer Surplus	Consumer Surplus	Total
Relative to MONOPOLY			
Europe	- 2 826	10 544	7 718
North-America	- 107 582	12 631	- 94 951
Rest of World	0	13 630	13 620
T O T A L	- 110 408	36 795	- 73 613
Relative to DUOPOLY			
Europe	- 2 826	- 905	- 3 731
North-America	11 974	- 1 405	10 569
Rest of World	0	- 958	- 958
T O T A L	9 148	- 3 268	5 880

The European producer surplus figures in table 4 do not include government subsidies. If indeed the projected \$ 20 billion subsidies were paid by European governments and financed by European tax payers there would be a redistribution of consumer and producer surplus. Market entry would cost European consumers roughly \$ 10 billion, but total welfare to Europe would remain unchanged. Taking these subsidies into account, government supported market entry by Airbus as an anti-monopoly policy - as it has been claimed by European governments - did indeed help consumers, but only those outside of Europe.

If market entry of Airbus is compared to the hypothetical situation of a duopoly with equal, mature producers a surprising welfare effect emerges. Overall welfare in the base case is by \$ 5.9 billion higher than in the reference situation. Consumers loose in all regions, but these losses are smaller than the gain in producer rents. Boeing has higher profits in the base case situation than two American producers in the hypothetical duopoly. Apparently the cost of late entry are more than compensated by another seemingly counter-intuitive effect.

Two forces, the scale and scope effects and the competitive effect, can explain this result. Because of increasing returns to scale the social optimum is one producer with marginal cost pricing and large output and consequently lower average and marginal cost. Insofar the simulated duopoly situation forces both producers up their average cost curves.

In the base case Boeing, of course, has lower and Airbus higher marginal cost than in the reference situation. But on average both producers together produce at lower average and marginal cost in the base case. This advantage does not show up in prices, it goes to Boeing in the form of profits. Therefore market entry of Airbus has forced Boeing into more competitive behavior than in a monopoly situation, but since Airbus is only a small producer the scale effects of Boeing with its projected market share of around 60% are strong enough to compensate for the high cost production of Airbus.

The simulations and the two alternative welfare comparisons in table 4 show that there is a conflict between competition effects, i.e. indirectly consumer welfare, and scale effects, i.e. overall welfare. Although the market is simulated to sustain two equal producers, welfare is larger in a monopoly situation and even an inefficient second producer

with small market shares is better than the hypothetical duopoly. This suggests that in the market for large transport aircraft scale and scope effects are strong enough to outweigh the output reducing effects of increasing market power and - in the extreme - of a monopoly. If the model represents the replacement of an established American producer by an European entrant, Airbus, the regional distribution of welfare changes looks ironic. Only North-America gains from the Airbus market entry.

#### PRODUCTION SUBSIDIES

Up to now simulations of industrial policy have only focussed on supporting market entry by subsidizing start-up investments. This policy has the effect of changing the incumbent's pricing policy. Entry deterring pricing strategies are not rational, if the commitment of European governments is credible as it was in the case of Airbus. These subsidies do not, however, influence the capacity game between the two producers. This can only take place if output decisions are influenced by production or price subsidies. It has been shown by BRANDER/SPENCER (1985) that the optimal export subsidy rate is that which moves the reaction function of the subsidized firm to that point which would have been chosen by the firm, if it were in a Stackelberg-leader position. Since in the present case not only exports but production in general is subsidized and there is domestic consumption, the optimal subsidy is higher than a subsidy on exports alone.

In order to determine the optimal subsidy for Airbus alternative subsidy rates have been simulated. It was assumed that only those aircraft types are subsidized in which Boeing has an advantage in terms of learning effects, i.e. short to medium range narrow-bodied and long range aircraft.

The Cournot-Nash game is played in the same fashion and parameter values are unchanged. Figure 1 summarizes the output effects of increasing subsidization of Airbus. Output is measured in total number of aircraft produced. Total output increases by only 6.6% if Airbus is subsidized with a 20% subsidy on price. Although only aircraft in two market segments is subsidized, Airbus increases its market share in all three segments: from 31% to 60% in the short to medium range, from 53% to 61% in the medium range wide-bodied, and from 45% to 53% in the long-range market.

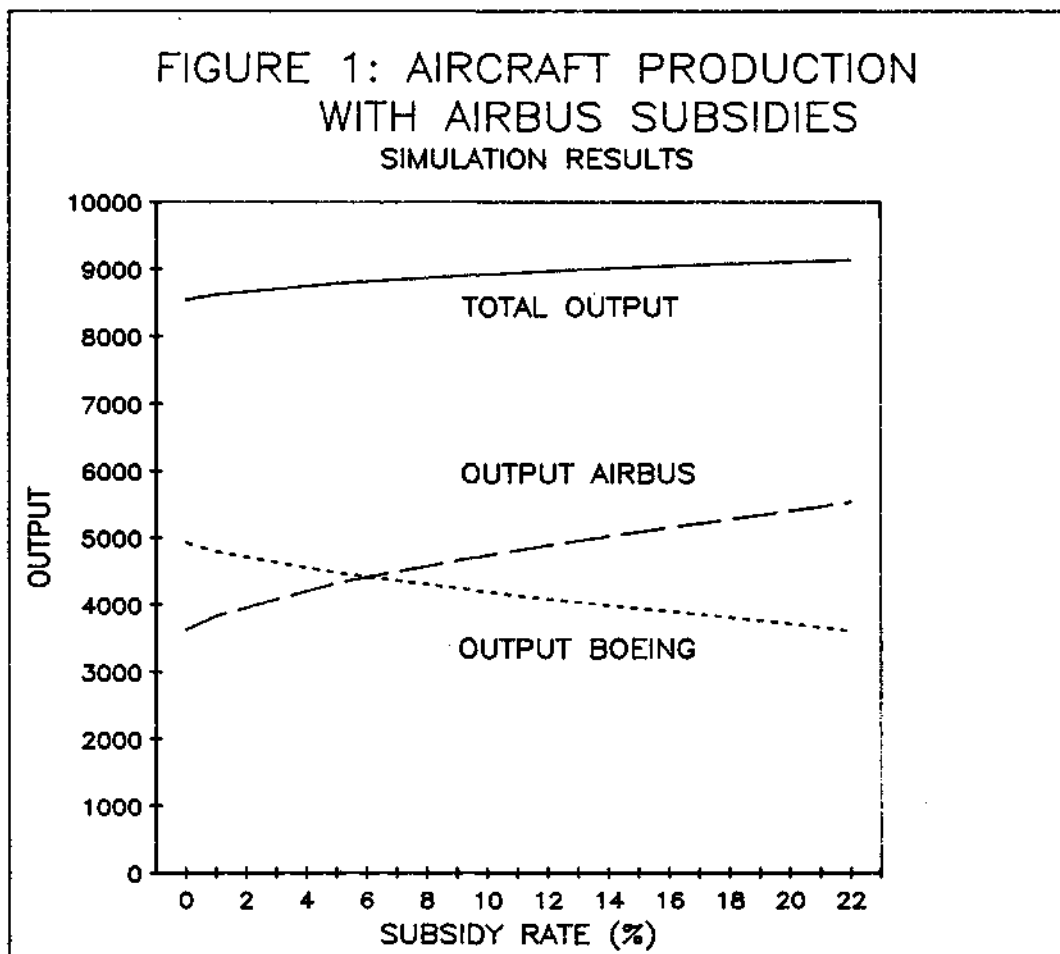
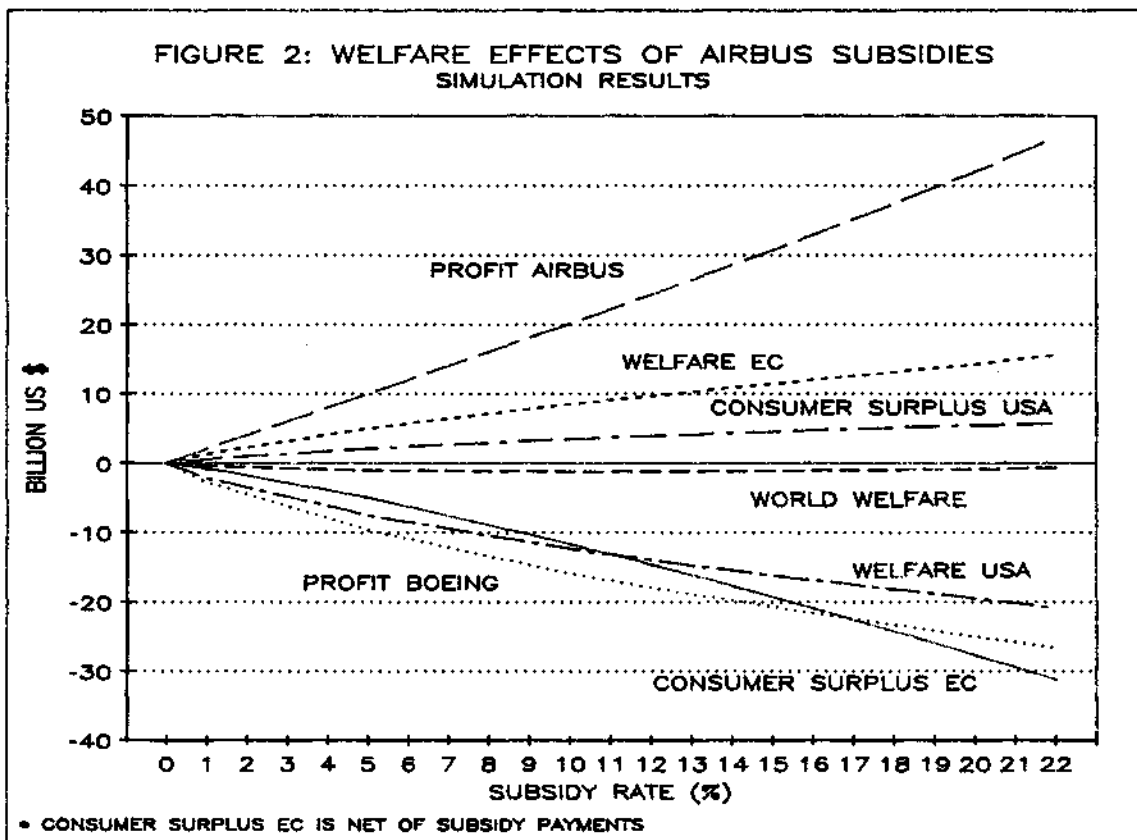


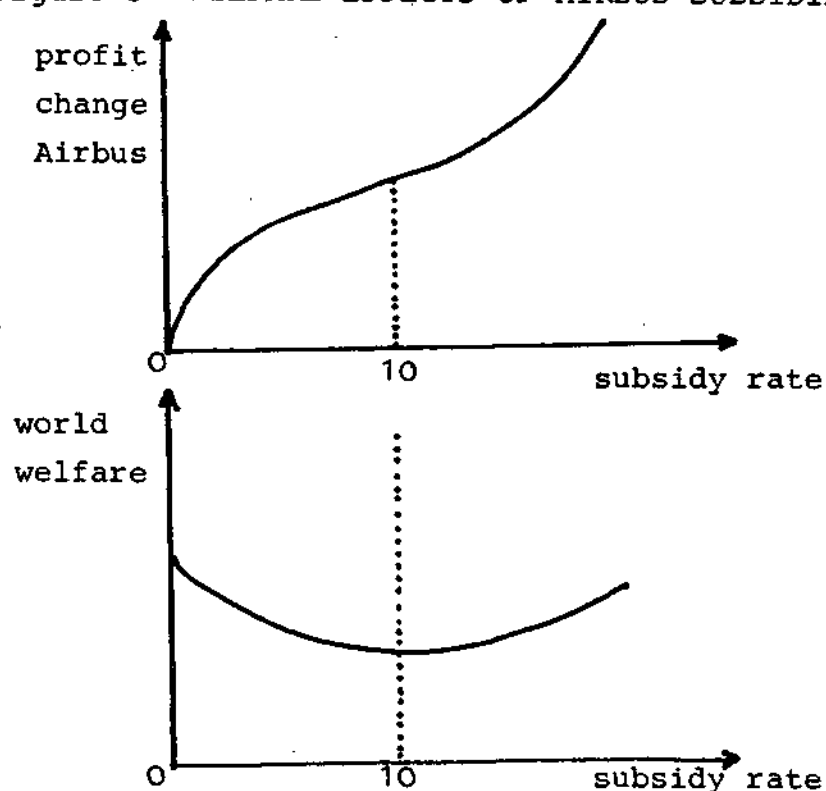
Figure 2 summarizes the welfare effects of increased subsidization. Profits increase faster than subsidies which does not come as a surprise since Airbus realizes learning effects through larger production, but since Boeing can sell fewer aircraft prices fall only slightly. Subsidization in a sense induces a transfer of learning effects from Boeing to Airbus leaving consumers relatively unaffected. European consumer surplus net of subsidy payment decreases, e.g. from \$ 33 billion to \$ 5.5 billion in the case of a 20% subsidy.

The effect on American and rest of the world consumers and producers is essentially the opposite. There are small gains in consumer surplus due to a slight fall in prices both in the United States and the rest of the world. Boeing's loss in profits is larger than Airbus's profit increases net of subsidy payments. World welfare decreases by less than 1%.



Production subsidies have been varied over a large range, but there is no profit or welfare maximizing subsidy like it is theoretically derived in BRANDER/SPENCER (1985). For subsidies higher than 22% no equilibrium can be simulated. The reason for this result is essentially the same as the one for the welfare effects of market entry of Airbus in the previous section. Airbus profits net of subsidies as a function of subsidy rates are S-shaped as shown in Figure 3 with an inflection point around a subsidy rate of 10%. This, incidentally, is also the minimum of world welfare (Fig. 3) and at this subsidy rate Airbus and Boeing have approximately equal market shares. The previous section has already shown that a monopoly is in overall welfare terms superior to the current situation and even to a duopoly of two identical producers. Welfare effects of production subsidies

Figure 3: WELFARE EFFECTS OF AIRBUS SUBSIDIES



follow the same logic. Increased subsidization of Airbus first leads to an equalization of market shares and therefore to higher unit cost on average. Hence world welfare is reduced and the cost advantage of Boeing becomes smaller. Only when subsidization increases beyond 10%, the difference in marginal cost become large enough to ensure that profits increase at a faster rate.

Regardless whether from a pure profit transfer perspective or an European welfare perspective it would be advantageous to subsidize the domestic firm to such a degree that foreign competitors are driven out of the market. This particular simulation result for the aircraft industry depends predominantly on the assumed existence of large economies of scale and barriers to entry. Even though the market is large enough to support two firms - at least in the calibration of this model -, a monopoly is superior to a duopoly in terms of world welfare. This result will most likely be true for industries with similar degrees of economies of scale. In that sense, there is a strong incentive to support one's domestic industry. Although in the present model Airbus is a producer with higher cost it is advantageous to support the inefficient firm. These arguments, of course, remain valid only as long as retaliation from foreign governments is not considered.

#### RETALIATION

The same logic according to which it is advantageous to subsidize Airbus of course applies to subsidizing Boeing. This even more so since Boeing has lower unit cost because of incorporated learning effects from prior production. Both governments therefore have equal incentive to subsidize their respective industries. The interaction of possible

outcomes is shown digrammatically below.<sup>1</sup> Whether any government has a dominant strategy depends on the outcome of subsidization with retaliation.

USA/Boeing	EC/Airbus	Subsidize	Do not Subsidize
Subsidize		?	Boeing Monopoly
Do not Subsidize		Airbus Monopoly	Duopoly (Status quo)

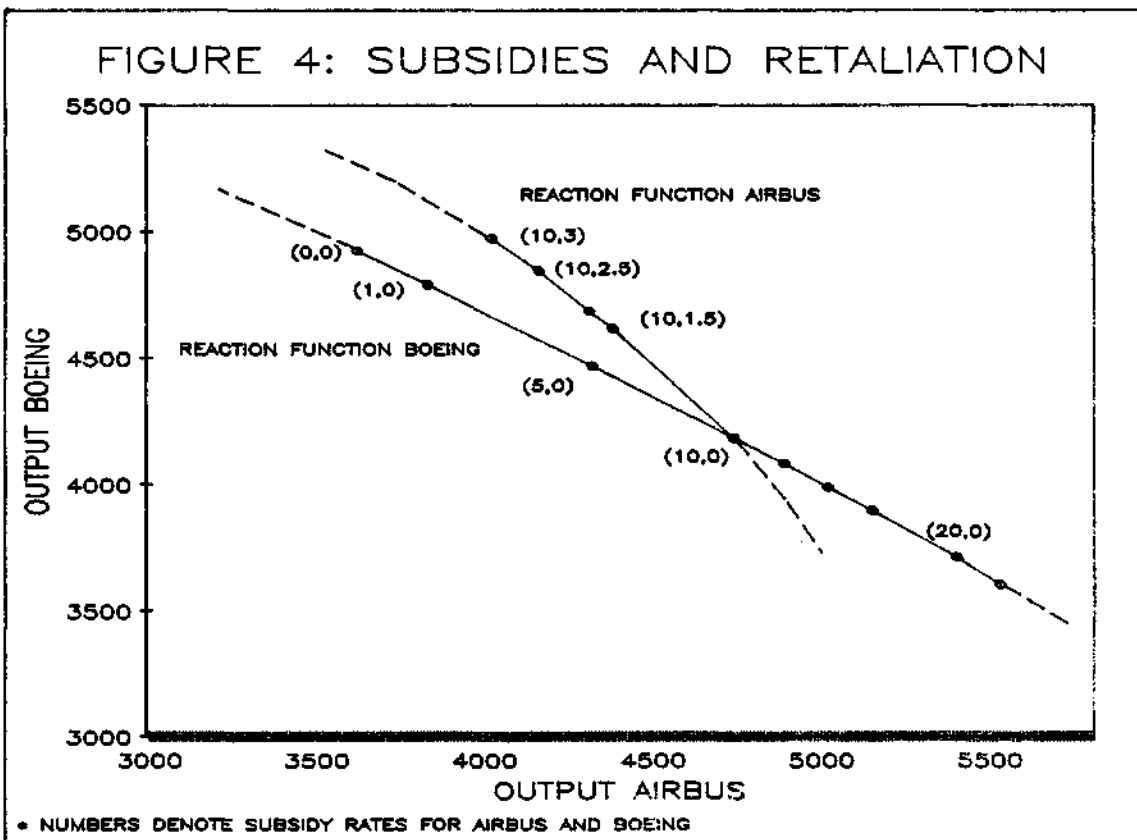
In BRANDER/SPENCER (1985) a Nash equilibrium in export subsidies exists. It is a Prisoner's Dilemma since both countries could be better off by jointly reducing subsidy levels, but would be worse off by unilaterally reducing subsidies. The equilibrium is characterized by a joint Stackelberg-equilibrium. In the simulation model of this paper an optimal unilateral subsidy level is not compabile with the existence of two firms. The same is true for retaliation against any subsidy which is low enough to allow both firms to stay in the market. Retaliatory subsidy rates also increase welfare of the retaliating country up to the point where the foreign firm is driven out of the market. Evidently there is no Nash-equilibrium in government subsidies in this model.

Although the outcome of subsidization with retaliation is uncertain, in the particular case of Airbus subsidies and potential American retaliation some inferences about the effectiveness of retaliatory measures can be made. Since

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<sup>1</sup> It is important to note that this comparison excludes all external economic or policitical cost of such governmental action.

Boeing is on a lower part of its learning curve than Airbus, one can expect that subsidies to Boeing will have a larger impact on Airbus than vice versa. Figure 4 illustrates simulation results of alternative levels of subsidies. On the reaction function of Boeing equilibria with unilateral subsidy rates of European governments to Airbus are shown.<sup>1</sup> For a 10% subsidy to Airbus retaliation of the American government through alternative subsidy levels are also simulated. They are represented by the points tracing out the reaction function of Airbus. One can easily see that rather low subsidy rates bring Boeing output back to levels without subsidization of Airbus. A 3% subsidy to Boeing costing about



<sup>1</sup> Subsidy rates are shown in brackets of Figure 4.

\$ 4 billion against a 10% subsidy to Airbus amounting to \$ 14 billion will bring Boeing output back to pre-subsidy levels and will therefore save the learning advantages vis-à-vis Airbus. Airbus profits will still be \$ 10 billion higher than in the case without subsidization, but net of subsidies an additional loss of \$ 4 billion will be incurred.

The question mark in the pay off matrix above will therefore clearly show that Boeing will most likely win a subsidy race against Airbus. Given this result the American government would have a dominant strategy consisting in subsidizing the production of Boeing in order to eventually reach a monopoly position. The European governments, on the other hand, do not have a dominant strategy. Given the dominant strategy of subsidizing Boeing, the sophisticated strategy of Europe and Airbus would be to close down Airbus instead of retaliating.

The dominant American strategy, of course, is an unrealistic hypothetical situation, since for external political reasons the American government will not unilaterally start to support Boeing. If a production subsidy race might start it will be initiated by Airbus subsidies and in that case the threat of retaliation by the United States is highly credible, since comparatively low subsidization has a strong impact on Airbus. It would be therefore rational for European governments not to start subsidizing Airbus.

## CONCLUSION

In this paper the allocation and welfare effects of industrial policy measures in an industry with strong economies of scale and high entry barriers have been investigated. Production of large transport aircraft has often been con-

sidered to be a prime candidate for which potential welfare gains through industrial and trade policy measures could materialize in a way similar to theoretical predictions. A stylized simulation model of competition in the aircraft industry is developed focussing on two distinct industrial policy measures: the support of European governments to Airbus Industrie in entering the market for large transport aircraft and, secondly, the potential impact of production subsidies taking into consideration unilateral action as well as possible retaliation.

Welfare effects of government supported market entry in the aircraft industry are somewhat difficult to interpret, because learning effects and economies of scope are so important that a monopoly would be maximizing world welfare - not considering distributional aspects. At the same time the market is large enough to support two producers. It is also ambiguous to which hypothetical situation government supported market entry of Airbus Industrie should be compared.

When Airbus entry is compared to a Boeing monopoly overall welfare decreases. This is so, because monopoly profits disappear and consumers gain in all regions, but by less than the profit loss. The reason for this result is, that the scale and scope effects of producing large transport aircraft are strong enough to outweigh the output reducing effects of a Boeing monopoly. From the viewpoint of European governments Airbus market entry as an "anti-monopoly" policy was not a successful policy. Only consumers in the rest of the world will gain. The negative welfare change does not come from the inefficient scale of production of Airbus relative to Boeing. This becomes apparent, when market entry is compared to a situation with two established American producers.

The high-cost production of Airbus yields higher welfare than a duopoly with two identical firms, because the scale effects of the large producer in the unequal situation dominate the competitive effects. Since consumers in all regions loose from Airbus entry and the American producer, Boeing, gains more than American consumers loose, the market entry of Airbus yield a positive welfare change only for North-America.

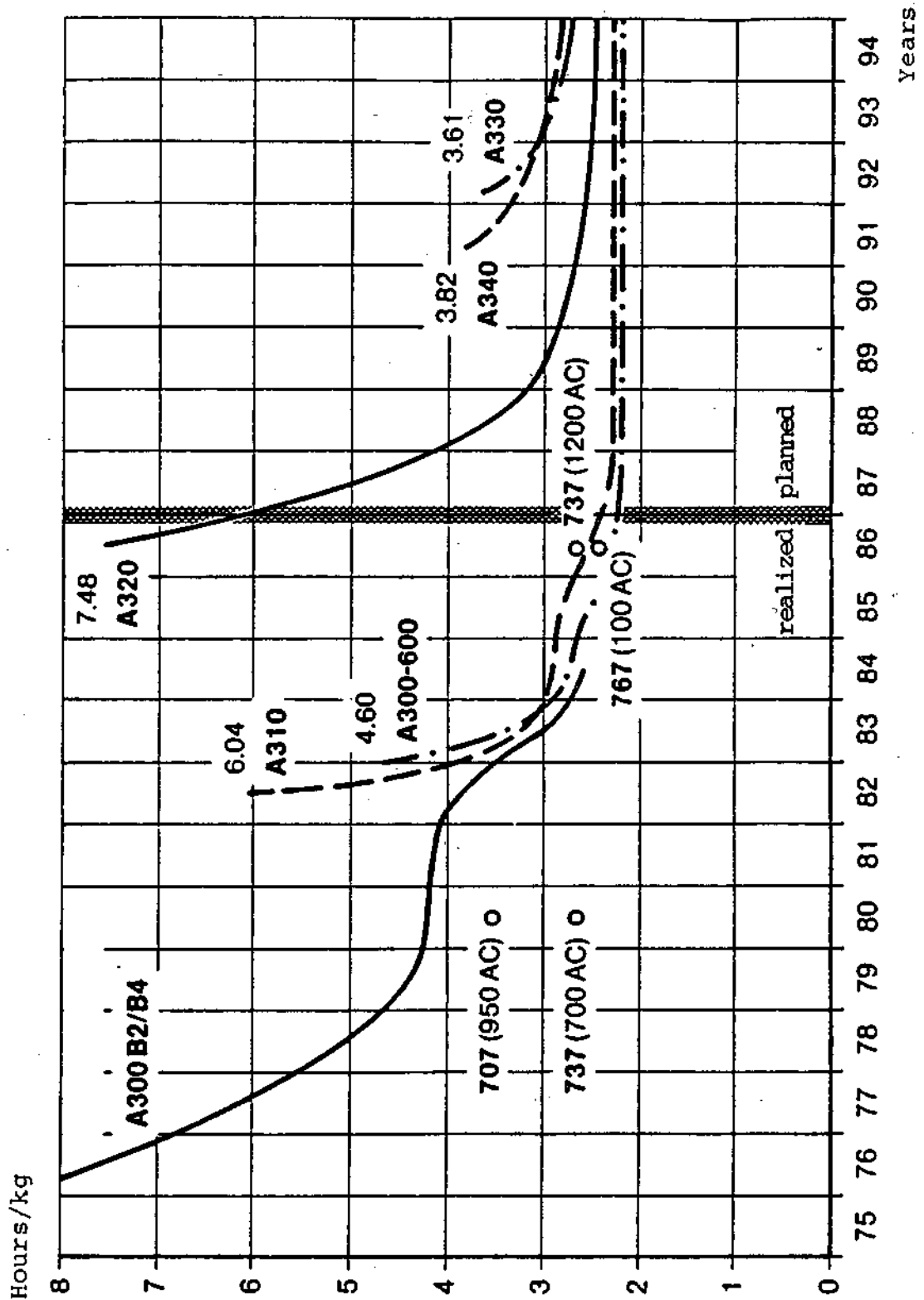
The basic logic behind these results is not special to the aircraft industry. If economies of scale are large enough a market structure with a few number of firms can emerge which is in welfare terms inferior to a monopoly. Because two or more firms can profitably stay in the market, economies of scale remain unexhausted and - at the same time - are larger than the losses in consumer surplus from monopoly pricing. In asymmetric situations, e.g. one large and one small firm, scale effects also come into play. In a symmetric equilibrium economies of scale are exploited to the least extent. The more asymmetric the equilibrium, the more consumers can gain from realized economies of scale of the large producers and still have the more competitive output policy. This logic is present in the analysis of production subsidies as well.

Airbus with a market share of about 30% is the smaller firm. Unilateral subsidization of Airbus will reduce world welfare because of the scale effect just mentioned. The welfare minimum is indeed reached when both producers have approximately equal market shares. Beyond that point it increases until the other producer leaves the market. Because overall welfare in a monopoly dominates oligopolistic industry structures and because of the fact that usually newcomers and relatively small industries are supported, the optimal subsidy is one which drives the other firm from the market, i.e. the Stackelberg-leader point is in a region of the other firms reaction function in which it incurs losses.

With subsidization amounting to a monopolization of the market retaliation is the natural consequence. The simulations show, that the incumbent large firm through small retaliatory subsidies can easily be brought into a position where support by the foreign government can be neutralized. The ability and willingness to retaliate should therefore effectively threaten any desire to improve the market position of a small firm by subsidizing it.

APPENDIX:

Figure A1: LEARNING CURVES FOR AIRBUS\*



\* MBB production share.

Source: MBB (1987).

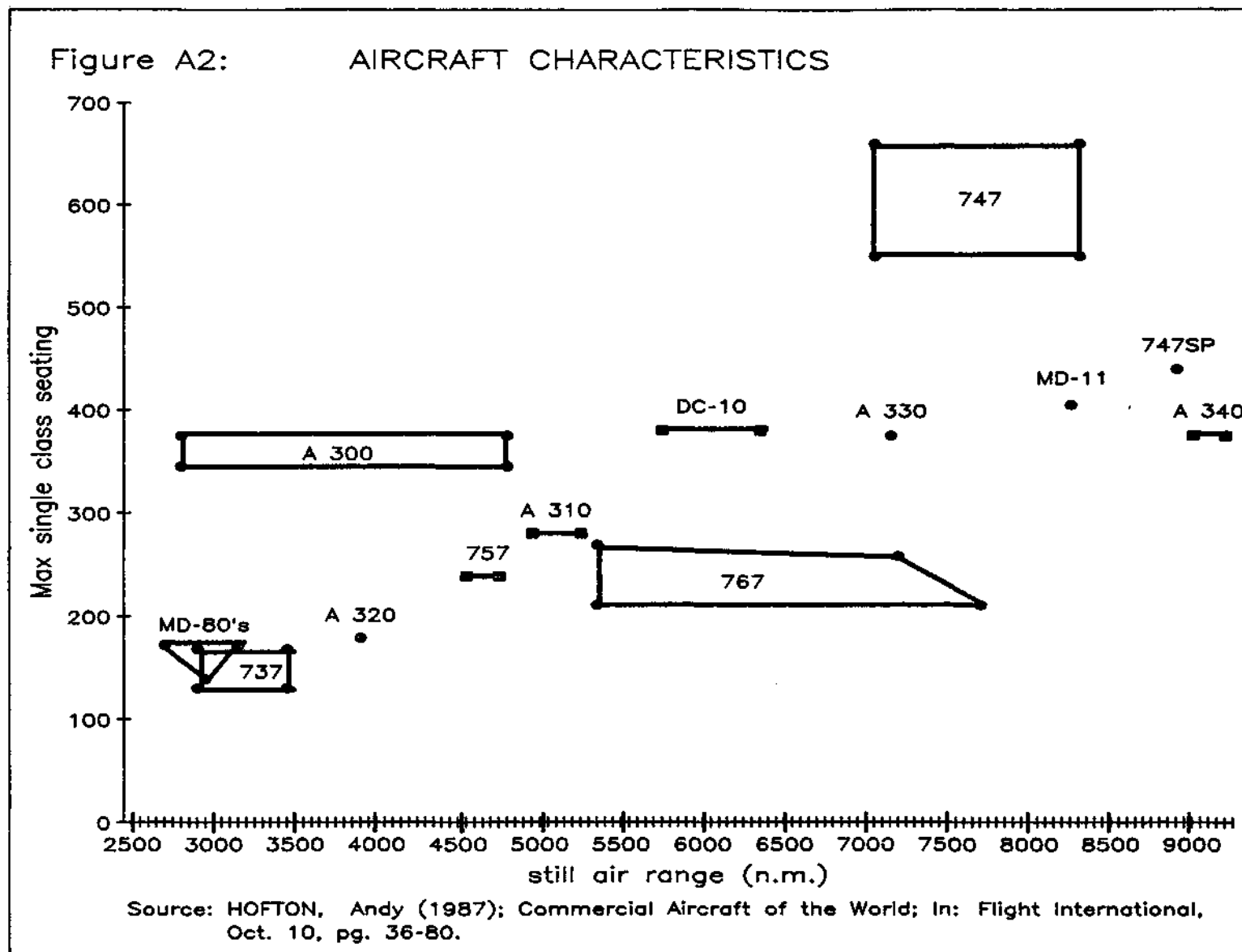


Figure A2: Aircraft Characteristics

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