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Entry into the market for large transport aircraft

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**ENTRY INTO THE MARKET
FOR LARGE TRANSPORT AIRCRAFT**

Gernot Klepper

May 1989

Institut für Weltwirtschaft an der Universität Kiel
The Kiel Institute of World Economics

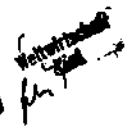
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INTRODUCTION

Large commercial aircraft is one of the areas in which the United States accuse European governments of unfair trade practices. The German Expert Council to the German government has also been highly critical about government support to AIRBUS (Sachverständigenrat, 1988). 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 will require several billion more in the next few years. The cause for these payments was 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.

In public many reasons are given to support the decision to enter this market; some are economic, some are political:

- There are only two American producers, with one producer, BOEING, having monopoly power in one market segment and this producer may in the future dominate the market.
- The aerospace industry is considered to be a catalyst of high technology as far as materials, electronics, and R&D management is concerned.
- About one half of aerospace turnover - in countries having such an industry - is military products. Since military procurement is highly volatile, capacity utilization can be improved if the share of military contracts is reduced.
- Spin-offs from military aerospace activities can be profitably used in civil activities.

These arguments all refer to the benefits of market entry, most of which are rather difficult to assess. Little is

known quantitatively about the economic impact of spin-offs and other external effects. It even remains an open question whether - without reference to these externalities - entry in the market for large transport aircraft by a European producer would be a profitable option from a business as well as a European or world welfare standpoint. The purpose of this paper is to investigate the likely results of market entry over the next two decades and to estimate the additional cost which a firm faces when it enters the market for transport aircraft late.

After a short historical review of the aerospace sector the characteristics of the industry as far as they are important for this study are reviewed. The Cournot-Nash model of a capacity game is then calibrated to the expected market for large transport aircraft. A monopoly and a duopoly with equal entry times as alternative market structures are simulated and compared to the calibrated model. Finally, the welfare effects of market entry are calculated with respect to these two alternative market structures.

MARKET STRUCTURE IN HISTORICAL CONTEXT

The dominance of American companies in the aerospace sector is a relatively recent phenomenon. Aircraft design and production started in Europe after World War I. It was dominated by military production. In the 1920's demand for aircraft in the United States was boosted by the federal government through its heavily subsidized air mail activities. In 1935 the United States became the largest producer of aircraft. During World War II production capacity was expanded massively so that at the end of the war a large industrial base could be converted to produce civil versions of military aircraft. With its large distances and low competition by railroads mainly the American market grew rapidly (U.S. Department of Commerce, 1986). Parallel to the increase in

demand in this period major technological advances took place. The introduction of the jet engine both in Great Britain with the "Comet" of de Havilland and in the United States with the B 707 of Boeing opened new opportunities in terms of speed and range.

The increase in demand and market size was accompanied by increasing concentration of aircraft manufacturers. In Europe French and British companies introduced new aircraft such as the Comet, the Caravelle, and the Concorde. All were unsuccessful commercially. In the United States the number of producers of large transport aircraft fell from about 30 in the 1920's to two after Lockheed opted out of the civil market in 1981.

It is this historical background which in the late 1960's confronted European governments and producers with the outlook that in the future only a small number of American producers would supply the market for transport aircraft. In addition, there was the danger that the aerospace sector overall would become an American monopoly, if the civil European production continued to be segmented and unsuccessful.

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 subcontractors 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 subcontracted 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 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. Whereas start-up investments and R&D are costly in absolute terms, the economies of scale are dominated by the learning effect which amount to 90 % of the overall economies of scale. 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". Figure A2 in the appendix illustrates this fact for the A300 and its deriv-

ative the A310 of Airbus. For a new generic aircraft the learning curve will start higher than those of the A310 and A300-600 in Figure A2, but it will most likely be lower than the original learning curve. 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).

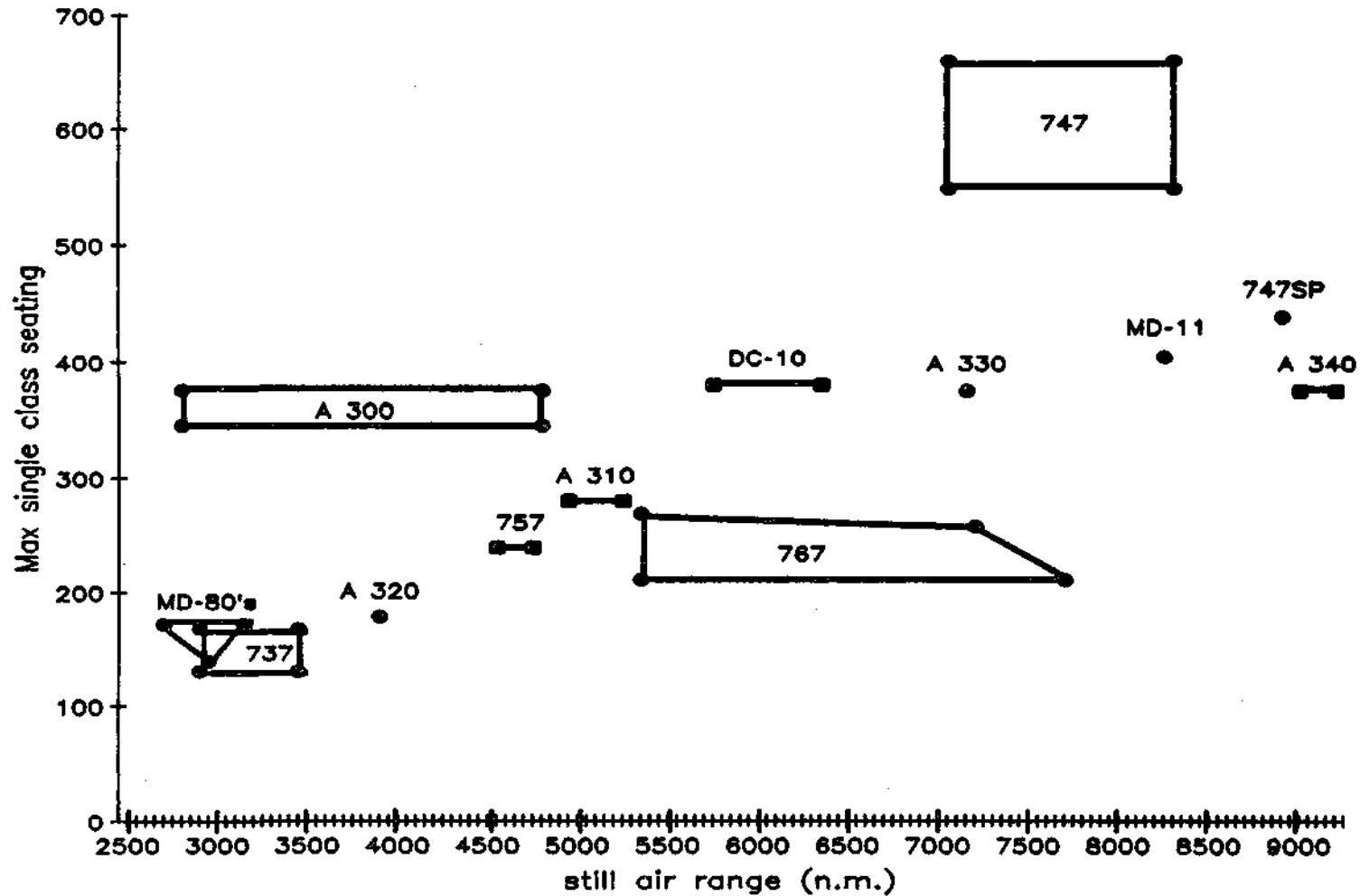
COMPETITION

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 1 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 air-

Figure 1: AIRCRAFT CHARACTERISTICS



Source: HOFTON, Andy (1987); Commercial Aircraft of the World; In: Flight International, Oct. 10, pg. 36-80.

lines 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 the market entry of AIRBUS was accompanied by heavy involvement of European governments. After several commercially unsuccessful projects European 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 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 (BERG/TIELKE-HOSEMANN, 1987, 1988), 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 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. Price competition by close substitutes such as the DC-10 depressed prices. 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 partici-

pating 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.

The capacity game over the next two decades and the allocation of resources in this industry will be the object of the analysis. In a model which simulates stylized features of the industry, it will be investigated how large the advantage of the incumbent firm still is more than 15 years after the entry of Airbus, and how this advantage may influence the capacity game and resource allocation for the next two decades. In other words, how much learning has to be invested until the entrant can compete on approximately equal terms is determined.

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 assures 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 not modelled. Since these subsidies are made dependent on the development of exchange rates neither their size nor their duration is known.

The short-run price game naturally can not be empirically investigated, since it depends on the actual development of demand in the future. The focus will be exclusively on the capacity game played between two producers which one could imagine as being Airbus Ind. 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 production 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

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

with F_{ik} fixed cost for product k

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

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

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 corresponding marginal cost of producing type k are

$$(3) \quad \frac{\partial C(x)}{\partial x_k} = \rho \beta_k a_k x_k^{\beta_k - 1} \left[\sum_{k=1}^m a_k x_k^{\beta_k} \right]^{\rho - 1}$$

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

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

$$(4) \quad \frac{\partial C(x)}{\partial x} = \rho \beta a x^{\rho \beta - 1}$$

with learning elasticity

$$(5) \quad \mu = \beta \rho - 1$$

In the general case with economies of scope, the height and shape of the actual learning curve is influenced by cross effects such that the learning elasticity in the production of type k becomes

$$(6) \quad \mu_k = \beta_k \rho \frac{a_k x_k^{\beta_k}}{\sum_{k=1}^m a_k x_k^{\beta_k}} - 1 + \beta_k \left[1 - \frac{a_k x_k^{\beta_k}}{\sum_{k=1}^m a_k x_k^{\beta_k}} \right]$$

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

$$(7) \quad p_k = p_k(x_k, x_{-k})$$

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

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

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 , $(\hat{x}_{i1}, \dots, \hat{x}_{im})$, is given by the m first-order conditions.

$$(8) \quad P_k \left(\sum_{j \neq i}^n x_{jk} + \hat{x}_{ik}, x_{-k} \right) \left[1 + \frac{\hat{x}_{ik}}{\varepsilon_k \sum_{k=1}^m \hat{x}_{ik}} \right] = \frac{\partial C_i(\hat{x}_i)}{\partial x_{ik}}$$

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

with ε_k = price elasticity of demand for product k .

(\hat{x}_A, \hat{x}_B) with $\hat{x}_i = (\hat{x}_{i1}, \dots, \hat{x}_{im})$, ($i=A,B$), is a Nash-Equilibrium if it satisfies equation (8) 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 air-

craft 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 practically all 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 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 A340 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:

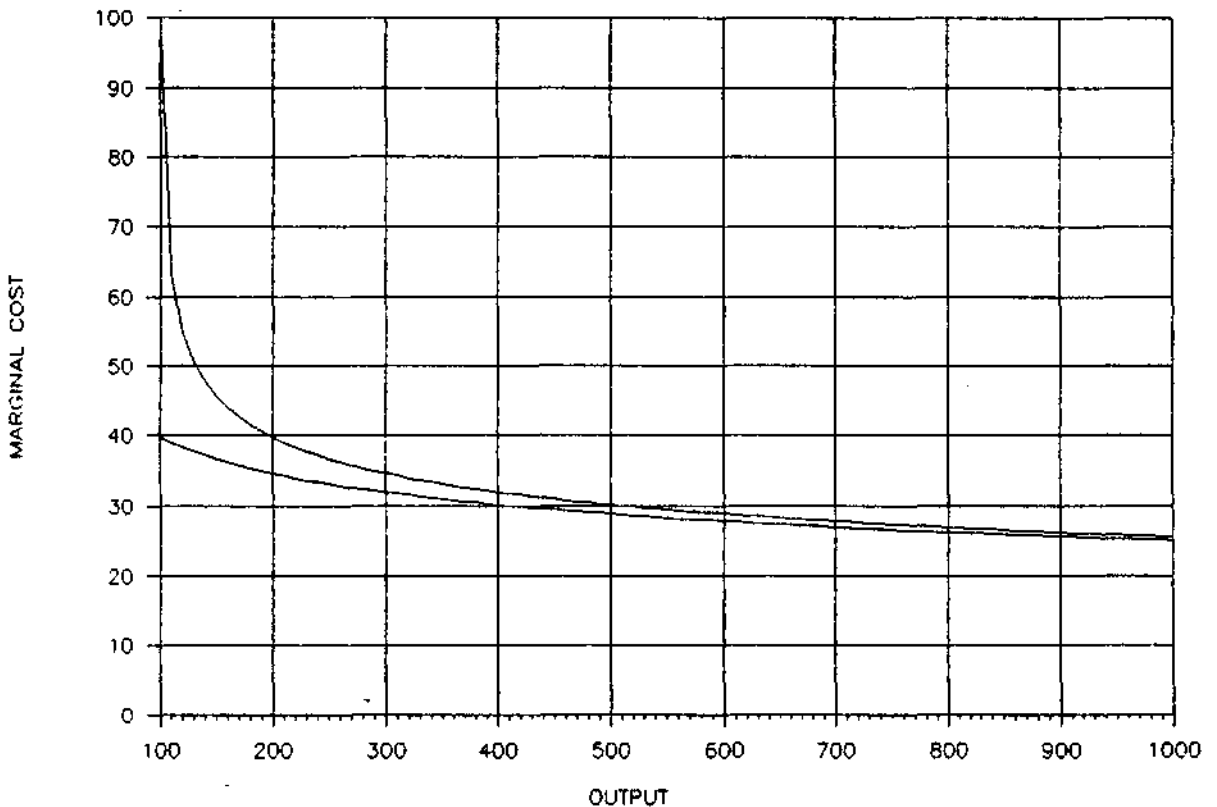
$$P_S=27 \quad P_M=62 \quad P_L=100.$$

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 (Berg/Tielke-Hosemann, 1987, U.S. Department of Commerce, 1986). (See figures A1, A2 in the appendix for some empirical examples). 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 time t is then given by the distance between the two marginal cost curves as it is illustrated in figure 2, where the cost of the first unit are normalized to 100 and the first producer has already produced 100 units when the second starts production. For the model calibration accumulated production of Boeing 737, 757, 767, and 747 and Airbus A300 and A310 in each market segment up to 1986 entered the cost function as already acquired learning effects.

Figure 2: Learning curve with elasticity 0.2



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/HESTON/SUMMERS, 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/Heston/Summers 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 most likely be rather small.

Since there is no indication how large a long-run price elasticity for aircraft might be in each market segment and for aircraft overall and since it is unknown how this elasticity might be perceived by producers, elasticities are endogenous in this model. It is assumed that identical firms would earn a rate of return of about 5.5 % and the demand function is accordingly calibrated to this rate of return. This is the way in which the capacity game is modelled here.

RESULTS

The model has been calibrated to the market forecast for the three market segments short range narrow-body (S), short/medium range wide-body (M), and long range (L). The technological characteristics of high fix cost and a learning elasticity of 0.2 are used for the calibration. The parameter value for the degree of economies of scope had to be chosen arbitrarily. Two alternative values are used to

investigate the effect of learning in previous aircraft when a new aircraft is introduced. The first is $\rho=.97$; it 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. The other value of $\rho=.985$ represents a cost saving of about 20 %.

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.

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 | |

*For Parameters see table A1 in the appendix.

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.

The summary in table 3 shows that 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-

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 % |
| *For parameter values see table A1 in the appendix. | | |

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 cost for a new generation aircraft.

ALTERNATIVE MARKET STRUCTURES

If the entry of Airbus is to be compared to a situation without entry, 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. In reality a complete monopoly might not materialize and another American producer like McDonnell Douglas may not be an equal competitor to Boeing.

Table 4: MARKET FOR LARGE TRANSPORT AIRCRAFT 1987-2006
Simulation: Monopoly

| | Market Segment | | |
|-------------------------|----------------|------|-------|
| | S | M | L |
| Output | 3201 | 3024 | 1419 |
| Marginal Cost | 17.4 | 44.3 | 50.1 |
| Price | 29.0 | 64.4 | 117.6 |
| Difference to Base Case | | | |
| Δ Output | -332 | -228 | -344 |
| Δ Price | +1.3 | +1.9 | +16.6 |

The monopoly allocation is summarized in table 4. All parameters are the same as in the base case, 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. Output, marginal cost, and prices are summarized in table 5. Only in the short range narrow-body market the overall output deviates significantly from the base case. The large learning incorporated in 1070 aircraft produced prior to 1987 in the base case has led to a diverging Nash equilibrium. Otherwise there is little deviation in the allocation from the base case.

Table 5: MARKET FOR LARGE TRANSPORT AIRCRAFT 1987-2006
Simulation: Duopoly with identical Producers

| | Market Segment | | |
|-------------------------|----------------|------|-------|
| | S | M | L |
| Output | 1850 | 1630 | 888 |
| Marginal Cost | 20.4 | 51.6 | 58.1 |
| Price | 27.1 | 62.4 | 100.4 |
| Difference to Base Case | | | |
| Δ Total Output | +167 | +7 | +13 |
| Δ Price | -0.6 | -0.1 | -0.6 |

However profitability is strongly affected. The simulation of identical firms produces a rate of return over the whole product cycle of 5.6 % for both firms, whereas in the base case Airbus had a rate of return of -1.2 % and Boeing +12.6 %. Competition among two equal producers leads to lower profit rates and lower total profits. The base case

has resulted in total profits for both producers of \$ 42.6 billion whereas two identical producers accumulate only \$ 33.4 billion.

The reason why output and prices vary little relative to the variation of profits comes from the dynamic learning effects. As one can see from figure 2 the difference in marginal cost between the two producers with different entry times becomes smaller and smaller as cumulated output increases. Also the reaction functions of the two producers are rather flat in the relevant range. Scale effects are so strong that an increase in the production of the other producer which reduces residual demand will be followed by only small quantity adjustments.

Figure 3: COURNOT-NASH EQUILIBRIUM

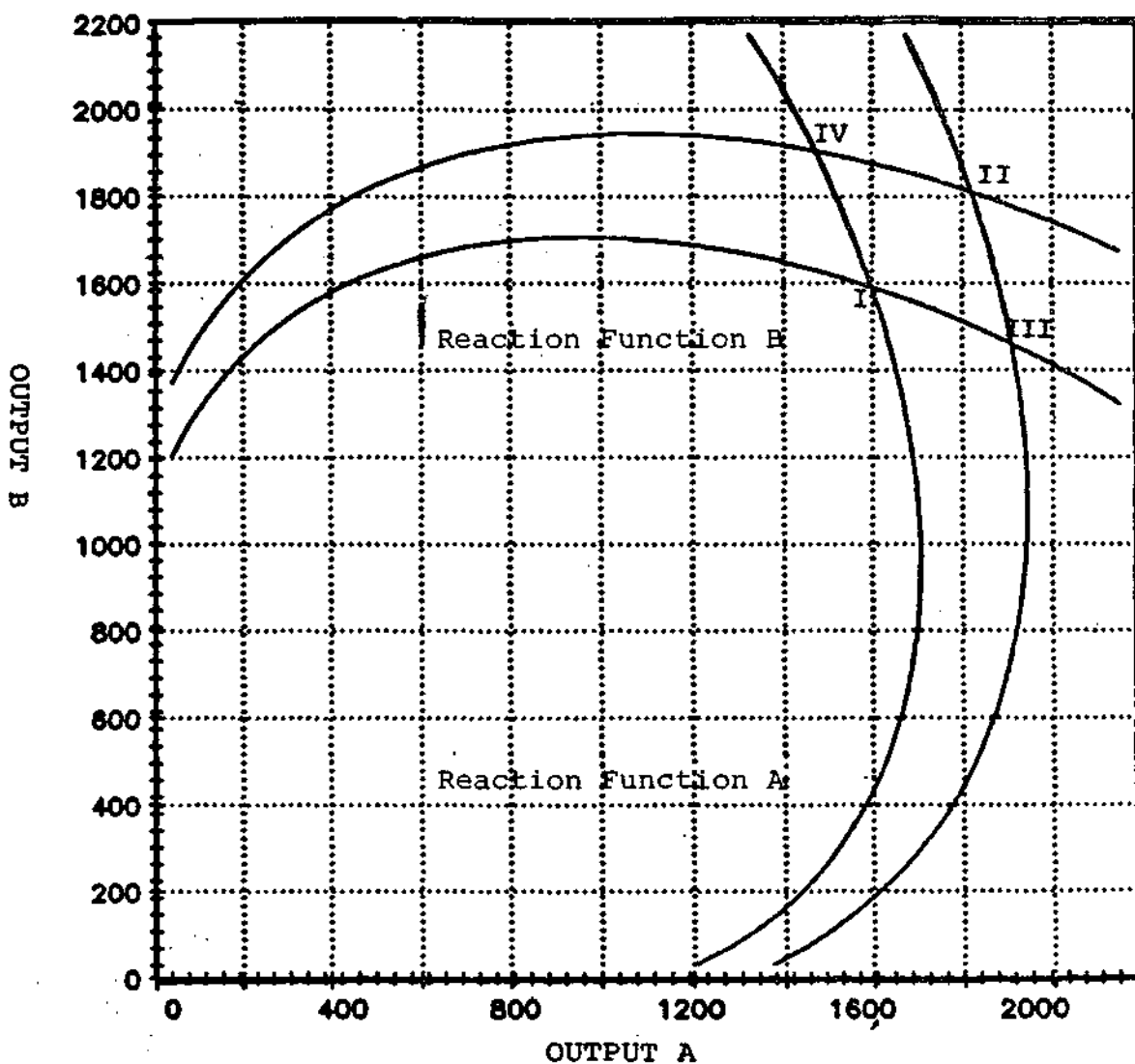


Figure 3 illustrates the shape of the reaction functions and the Nash-equilibria for alternative parameter values in an one-product model with similar parameter values. The lower reaction functions represent about 7 % higher marginal cost than the higher functions, i.e. equilibria III and IV characterize firms with 7 % marginal cost differentials.

WELFARE

Not only the distribution of producer rents is affected by market entry, but consumers - i.e. airlines and indirectly airline passengers - will bear the cost or benefits of this decision. Like in the computation of the producer cost of market entry the base case allocation can be compared to the two hypothetical alternatives: monopoly and duopoly of established producers. Table 6 summarizes the change in consumer surplus by comparing the base case with the alternatives. Market entry could be considered a successful anti-monopoly policy from a consumer standpoint. It has welfare benefits amounting to \$ 36.8 billion of which the largest share comes from the long-range market segment. If the alternative market structure without market entry would be a duopoly consumer surplus is slightly negative.

Table 6: CONSUMER SURPLUS CHANGE BY MARKET SEGMENT
(Mill. \$)*

| | S | M | L | Total |
|----------|-------|------|-------|-------|
| Monopoly | 3798 | 6460 | 26538 | 36795 |
| Duopoly | -1940 | -279 | -1049 | -3268 |

*Consumer surplus change: Consumer surplus base case - consumer surplus alternative market structure.

When total welfare effects of government supported market entry are considered it is of particular interest to compute the regional distribution of welfare effects. On the producer side it is assumed that purchases of the producers are bought from competitive markets so that profits of Airbus and Boeing are equal to producer surplus. For the distribution of consumer welfare forecasted regional market shares (AIRBUS INDUSTRIE, 1987), were used.

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 (Table 7). 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 7: DISTRIBUTION OF WELFARE EFFECTS OF MARKET ENTRY

| | Producer Surplus | Consumer Surplus | Total |
|------------------|------------------|------------------|-----------------|
| 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 |
| 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 7 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 effects, 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 7 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.

CONCLUSIONS

Entry in the market for large commercial jet aircraft is both expensive in terms of high start-up investment which is sunk to a large extent and expensive in terms of the time it takes until the entrant becomes an established producer. The entry of Airbus has been heavily supported by European governments. The question what the outlook is for the next one or two decades has been investigated in this paper.

The capacity game between two producers has been calibrated to the expected market from 1987 to 2006 as it is seen by the producers themselves. The technological characteristics such as economies of scale and scope as well as learning

effects are incorporated in the model. Since there is very little information on cost structures of producers and demand elasticities these parameters were calibrated to the expected market. It was assumed that both producers have available technologies of equal efficiency. The degree of economies of scope was completely unknown. A variation of this parameter in realistic bounds did not change the qualitative results of the paper (tables A2 and A3).

The calibration showed that it takes a long time to overcome the disadvantage of late entry in this industry. By the year 2006 the entrant Airbus will come close to breaking even. The low profitability mainly stems from the heavy start-up costs in the 1970's. If one ignores this investment, Airbus is profitable in the period from 1987 to 2006 but much less so than Boeing. The market shares resulting from the calibrated capacity game coincide with expectations by some producers. The structure of the results suggest that in the presence of capital cost and without government support through subsidies market entry is unlikely.

If market entry is compared to alternative histories such as a monopoly situation or a duopoly of established producers, two results are remarkable. If one considers that the model covers 20 years of production, there is little variation in output and prices under the alternative simulations compared to the base case calibration. Under monopoly output is about ten percent smaller and prices only slightly higher in segments S and M, whereas in L prices rise by a little more than 15 %. In the duopoly simulation prices and output essentially do not change. Only output in segment S is larger than in the base case, because the base case disadvantage was very strong. Hence consumers are little affected by this market entry when it is compared to other possible developments of market structure.

The main difference in the alternative courses of events appears in the profitability of the firms. In the base case

the incumbent has high profits - rate of return of 12.6 % - when compared to the simulation with two established firms - 5.6 % rate of return. A monopoly situation of course would increase profits even more, since large learning effects can be realized. The entrant Airbus pays for the higher profits of Boeing. If one assumes that by the end of the capacity game which has been simulated here the two firms are both mature producers, then one can calculate the cost of market entry for Airbus. Profits over the whole product cycle in the base case simulation are compared to profits derived from the simulation of two established firms. An overall loss in the market entry case of \$ 2.8 and an overall profit in the duopoly case of \$ 16.7 amount to a difference of \$ 19.6 billion. This does not include the launch cost which an entrant has to bear in the same way as an incumbent. It comes from the cost disadvantage of starting production later than the incumbent, i.e. it is a learning cost phenomenon and not a fix cost phenomenon.

Overall welfare effects of the Airbus market entry depend on the market structure to which the allocation is compared. Compared to a Boeing Monopoly overall welfare is lower with Airbus. 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.

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 lose, the market entry of Airbus yield a positive welfare change only for North-America.

Figure A1: LEARNING CURVES FOR AIRBUS* AND BOEING

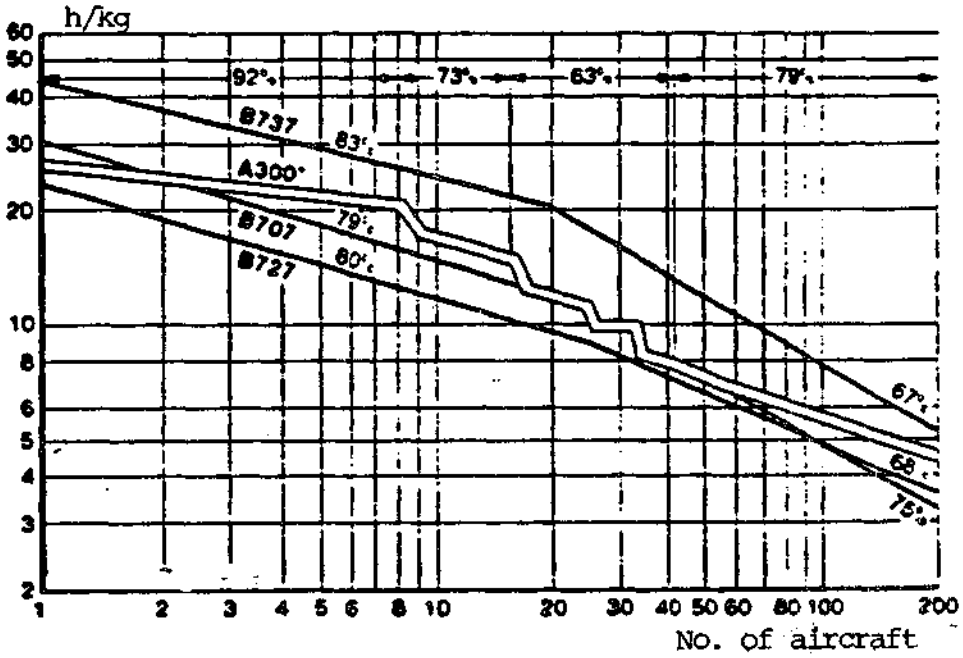
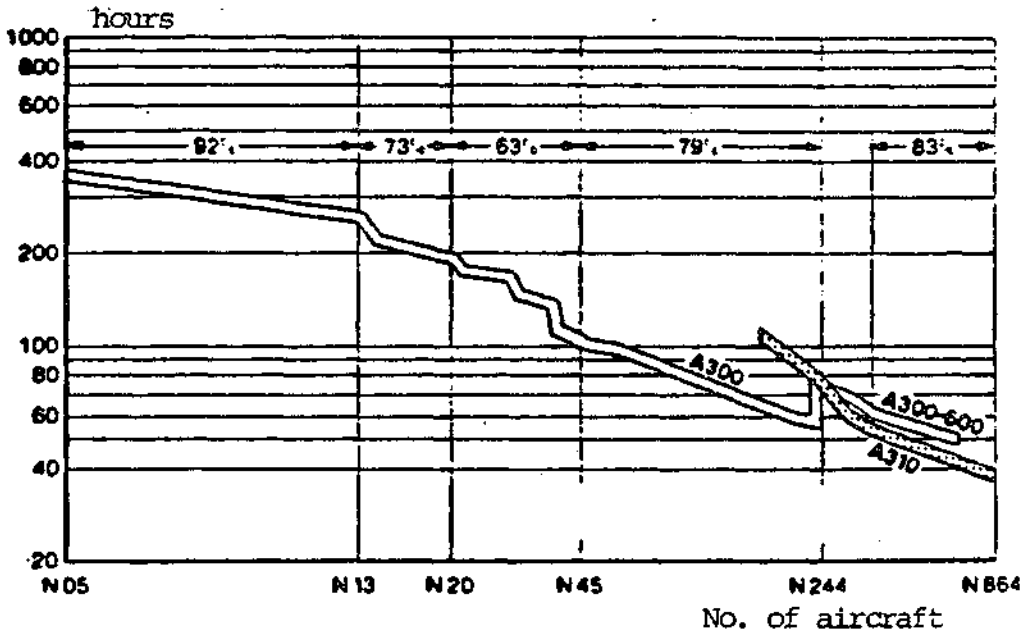


Figure A2: LEARNING CURVE - A-300 and Derivates*



* MBB production share.

Source: Flosdorf, H., Stand und Chancen des Airbus-Familienprogramms, in: Schulz, W. and Wilke, W. (eds.), Jahrbuch der Deutschen Gesellschaft für Luft- und Raumfahrt e.V., Köln 1980, Vol. I, p. 020-1.

Table A1: PARAMETER VALUES FOR BASE CASE

$\rho = 0.97$
 $\beta = 0.811$ for $i=A,B$ and $k=S,M,L$

| | S | | M | | L | |
|---------------------|------|------|------|------|-------|------|
| | A | B | A | B | A | B |
| F_{ik} | 4000 | 3000 | 4000 | 4000 | 4000 | 3000 |
| Previous production | 0 | 1070 | 288 | 149 | 0 | 609 |
| a_{ik} | 166 | | 400 | | 415 | |
| Demand Constant | 37.5 | | 81.0 | | 176.0 | |

Table A2: PARAMETER VALUES FOR ALTERNATIVE ECONOMIES OF SCOPE

$\rho = 0.985$
 $\beta = 0.805$ for $i=A,B$ and $k=S,M,L$
 $a_{ik} = (140, 340, 375)$

Table A3: MARKET FOR LARGE TRANSPORT AIRCRAFT 1987 - 2006

Base Case Calibration, $\rho = 0.985$

| | Market Segment | | | | | |
|---------------|----------------|--------|--------|--------|--------|--------|
| | S | | M | | L | |
| | Airbus | Boeing | Airbus | Boeing | Airbus | Boeing |
| Output | 1206 | 2408 | 1874 | 1395 | 756 | 948 |
| Market Share | 33.4 | 66.6 | 57.3 | 42.7 | 44.4 | 55.6 |
| Marginal Cost | 23.0 | 18.7 | 50.0 | 53.2 | 67.6 | 58.6 |
| Price | 27.4 | | 62.5 | | 103.7 | |

Simulation: Monopoly

| | S | M | L |
|---------------|------|------|-------|
| Output | 3137 | 2868 | 1362 |
| Marginal Cost | 17.9 | 46.4 | 55.6 |
| Price | 29.3 | 65.6 | 120.5 |

Simulation: Duopoly with Identical Producers

| | S | M | L |
|---------------|------|------|-------|
| Output | 1877 | 1645 | 860 |
| Marginal Cost | 201 | 51.3 | 62.0 |
| Price | 26.9 | 62.3 | 103.0 |

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