CYCLES

IN THE AIR TRANSPORTATION INDUSTRY

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1. INTRODUCTION

Cycles in the economy are a widely recognized phenomenon (see for example Schumpeter, 1939). Although the existence of long term cycles is not clearly proved, medium term cycles, averaging a 7 to 10 year period, and formerly known as Juglar cycles, are seldom questioned. The phenomena inducing those cycles, however, are complex and still a subject of research.

In air transportation, cycles have been observed and commented upon, especially those concerning the airlines (periodicity of financial results), and the aeronautic industry (cycles of orders). Specialized magazines (Avmark Aviation Economist, Airline Business...) release articles on this subject periodically, and try to prophesy when will the next downturn come and how bad it is going to be.

Those cycles seem to find their origin, at least partially, in the pattern of demand growth, which is itself linked to the evolution of economic activity. It has been indeed repeatedly observed throughout the world that traffic evolution is statistically correlated to economic growth (usually measured by GDP or GNP growth). Traffic forecasts (Yearly passenger traffic growth) released every year by several organizations (ICAO[1], IATA[2], Boeing, Airbus...) are based on the assumption of a linear correlation between GDP growth and traffic growth

Much more, however, can be drawn from the observation of aviation cycles, in relation to economic cycles. The relations between economic growth, traffic growth and aviation cycles are indeed an interesting subject of study : can a whole system a relationship be built between the variables of interest ? How are related traffic, financial results of airlines, aircraft orders and deliveries ? How can minor variations in traffic, result in airline cycles of such magnitude (14 MD USD lost between 1990 et 1994) ? Why is air transportation such a chaotic system ?

As statistical analysis results provided in this paper point out, the answer comes mainly from the behavior of the actors of this industry. In an oligopolistic sector, like the air transportation industry, strategic behavior matters. This leads us to try to understand the dynamic structure of reactions of airlines to fluctuations of traffic and to good and bad fortunes. A game theory framework (D. Fudenberg, J. Tirole, 1991) can be used to analyze the interplay of the airlines decisions in terms of investment. Do they take a long term view, or do they have a myopic strategic behavior ?

This is therefore the aim of this paper to analyze aviation cycles by using statistical methods, and from there to build a model of airline behavior, using a game theory framework, to account for observed reactions in cycles.

The outline of the paper is the following : First the theory of economic cycles is briefly reviewed (part 2). Then, using long time series data on world GDP and traffic, the link between economic cycles and traffic is discussed (part 3), as well as the relevance of other indicators. In a fourth part, relations and time lags between relevant aviation activity variables are studied and their relations with economic cycles discussed. Finally (part 5), a game theory framework is used to give an explanation of the airlines behavior, which

[1] *International Civil Aviation Organization*
[2] *International Air Transport Association*

results in an amplification of economic cycles in the airline industry. We conclude by suggesting ways of smoothing the cycles through a better management of capacity investments.

Can the aviation cycle be broken ?

2. CYCLES AND THE ECONOMY

Historians and economists have observed that fluctuations, more or less important, with different duration, occur in the economy since the advent of the industrial era. Since Adam Smith (1776), numerous theories have been put forward to account for economic growth, and for cycles affecting this growth[3] (for a review of these theories see for example Boyer, 1990). Neglected after world war II, because growth was strong and continuous, with no more important cycles, those theories have been considered with renewed interest in the seventies. In those years, the economic miracle of after war decades has faded away, and been replaced by more troubled times. Important cyclical economic fluctuations reappear, and with them, attempts to find explanations (Zarnovitz, 1985).

Without explaining details of numerous and complex models, it is useful to understand that basically two types of explanations exist for cycles : Some explanations state that the causes of cycles are exogenous events (an oil crisis for example), while at the other end of the spectrum, others consider that cycles are inherent in capitalistic economies (Marx was the first to provide such an explanation), and can therefore be explained in terms of economic mechanisms (adjustment of supply and demand, monetary disequilibrium...). As often when dealing with complex phenomena, the truth certainly lies somewhere in between those extreme conceptions. More recent research concentrate on modeling the dynamics of economic systems, using complex mathematics models (dynamic systems, chaos theory...) and emphasize the fact that previous models of cycles, without being totally mistaken, had only a partial view of the situation. It is now clear that no simple model can account for such complex phenomena, even if certain models had some relevance in their times.

3. ECONOMIC CYCLES AND AVIATION CYCLES

In air transportation, strong cyclical phenomena have been noticed, and the pattern seems to get stronger with time (see for example graph 4.1). Different situations may prevail in different markets (Europe, USA, Asia), but since the industry tends towards globalization, and competition becomes worldwide, what affects one market affects others in several ways. It does not seem, therefore, an oversimplification to speak about global cycles in air transportation. The growing interaction of markets may also account, at least partly, for the amplification of cycles that seem to appear.

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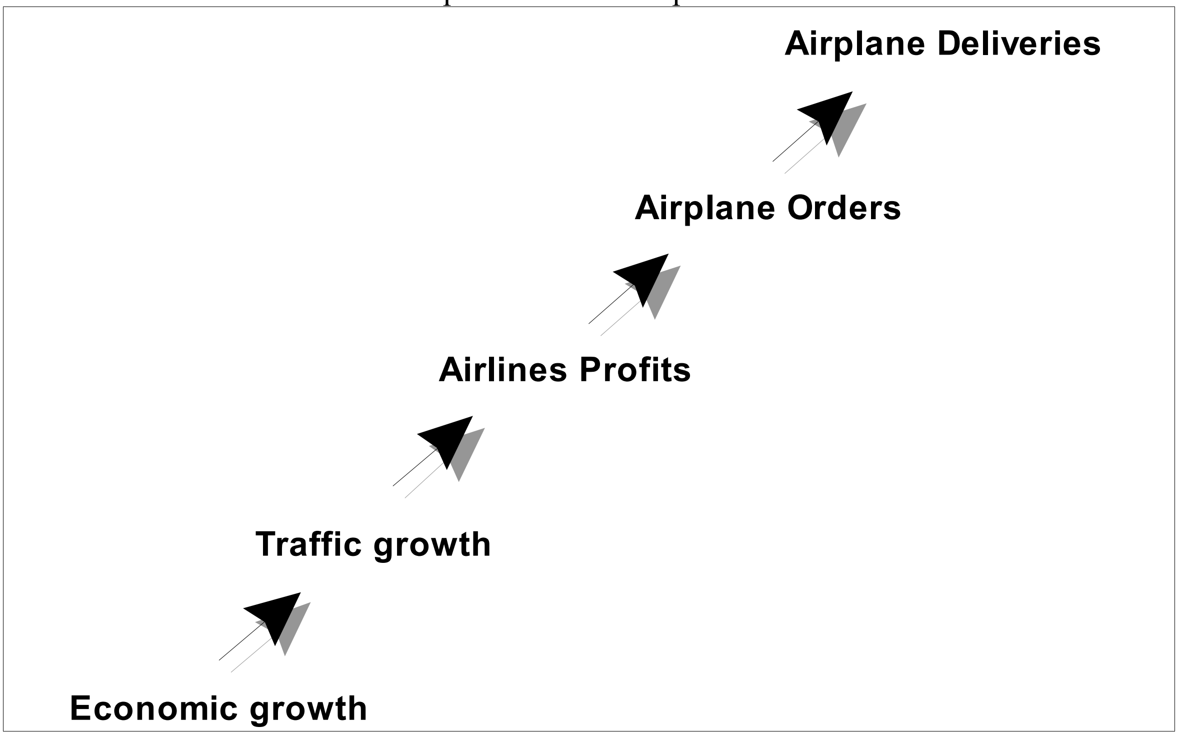
[3] *Most major economists have contributed to the theories of growth : Smith, Ricardo, Malthus, Marx, Von Neumann...*
Some have tried more particularly to explain cycles :Samuelson, Schumpeter, Hayek...

As with economic cycles, two explanations are possible : cycles can have external causes (economic cycles, oil crisis), or can be linked to internal phenomena (behavior of actors :supply, demand, investment...).

External causes are most of the time deemed responsible for cycles in air transportation. It is not rare to see the sequence of events represented in the following way :

Graph 3.1 : A too simple view



This analysis is only partly relevant, as I shall demonstrate in part 4. It obliterates the role of the airlines in terms of strategies, and makes profits depend only on external factors, which is obviously not true in an oligopolistic industry.

The first part of the sequence, however, linking economic growth to traffic growth, can hardly be disputed.

The correlation between GDP growth and traffic growth has indeed been very often remarked and widely commented upon. GDP growth (or the like) is generally used when traffic forecasts are computed (although GDP growth is in no way easy to forecast itself !). Various organizations compute yearly traffic forecasts, on international level (ICAO, IATA, Boeing, Airbus), and national level (various civil aviation authorities throughout the world, for example DETR[4] in the UK), using as main variable, forecasts of GDP growth.

This correlation indicates either a strong dependence of traffic growth on economic growth, or the fact that factors affecting economic growth, in a positive or negative way,

[4] *Department of the Environment, Transport and the Regions*

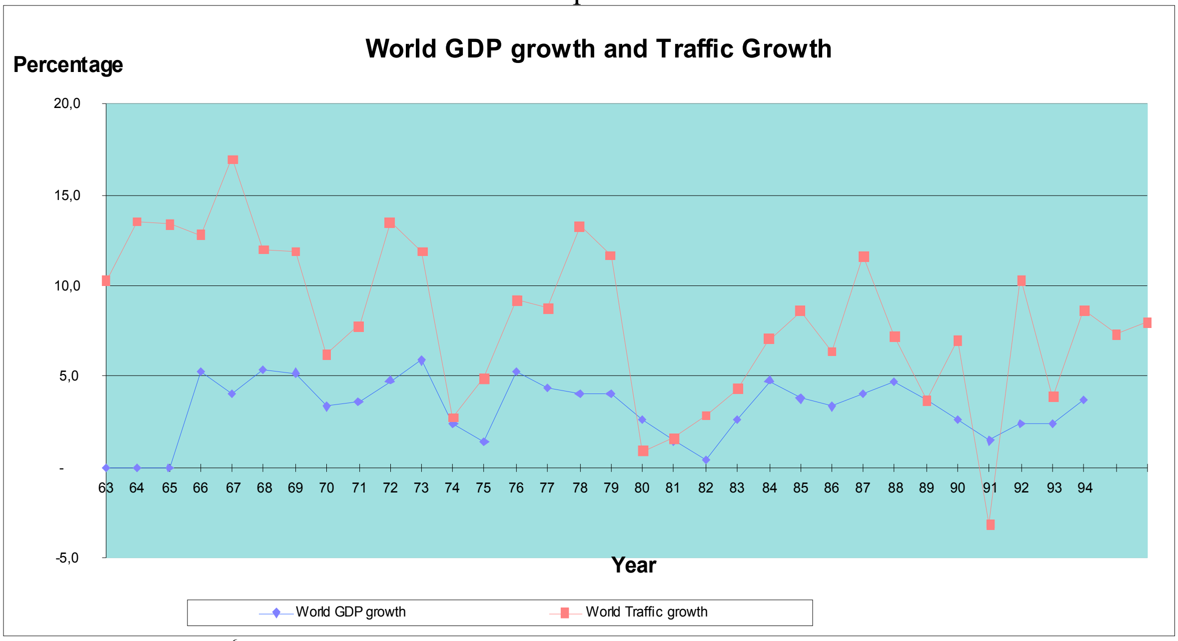
also influence traffic growth[5]. Both these explanations are most certainly partly true. For example, a significant increase in oil prices has at the same time repercussions on many levels of the economy, thus affecting air traffic demand, and has also a direct effect on airline costs and prices, and therefore on traffic.

The examination of time series data on world GDP and world traffic, from 1971 to 1996 (past data are less reliable due to lack of USSR data), show us that the correlation between GDP growth ($\Delta GDP_y = GDP_y - GDP_{y-1}$) and traffic growth ($\Delta Traffic_y = Traffic_y - Traffic_{y-1}$), where y is the year, is high :

$$Corr(\Delta GDP_y, \Delta Traffic_y) = 0.73$$

ΔTraffic and ΔGDP usually fluctuate in the same direction, but traffic has a much more chaotic pattern. Variations in traffic growth tend to be more important and exhibit a slight downward trend.

Graph 3.2



sources : ICAO, IMF[6]

Regressions can be performed to confirm this analysis. The regression results shown in the table 3.1 confirm that 61 percent of the variability of traffic growth can be explained by two variables : GDP growth and a time index. Those results are significant from a statistical viewpoint. The coefficient of the time index is negative, showing a slowdown in growth as time passes ; this can be interpreted as a saturation of traffic demand, noticed in industrialized countries (especially North America) where the growth experienced in past decades tends to weaken.

[5] *Correlation does not mean causality* !

[6] *IMF :International Monetary Fund*

Table 3.1 : Traffic as a function of GDP

$$\Delta traffic = \alpha + \beta \quad \Delta GDP + \gamma \quad Year$$

Data sources :

Δtraffic	ICAO (World Civil Aviation Statistics)
ΔGDP	IMF (World Economy Outlook)

Multiple Regression Analysis :

Dependent variable: Δtraffic

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	318,437	144,476	2,20409	0,0383
ΔGDP	1,89325	0,398489	4,75107	0,0001
Year	-0,160466	0,0726935	-2,20744	0,0380

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	222,931	2	111,465	17,21	0,0000
Residual	142,523	22	6,47834		
Total (Corr.)	365,454	24			

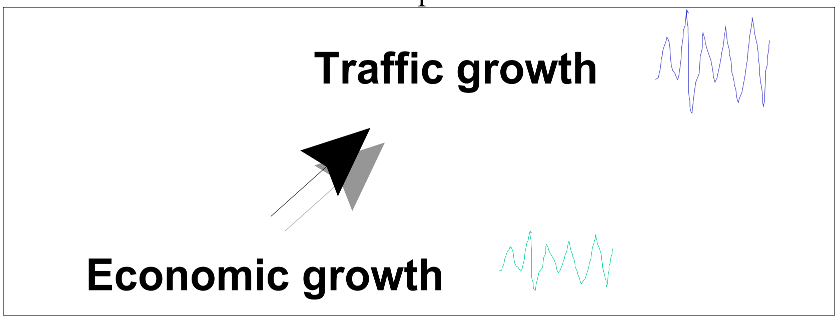
R-squared = 61,001 percent
R-squared (adjusted for d.f.) = 57,4557 percent
Standard Error of Est. = 2,54526
Mean absolute error = 1,9726
Durbin-Watson statistic = 2,42495

sources : ICAO, IMF

More accurate analyses could obviously be done in distinguishing geographically between countries or groups of countries, and using other economic data, but our main purpose here is not to perform such analyses but to examine the links between economic cycles and aviation cycles, on a worldwide basis.

The first part of the link has therefore been confirmed, and even if economic growth is certainly not the only cause of traffic growth (behavior of airlines does matter), it remains the main determinant when one looks for a global explanation of traffic growth.

Graph 3.3



4. CYCLES IN AIR TRANSPORTATION

4.1 Choice of variables

First, let us examine how can aviation cycles be meaningfully described. All variables relevant to the aviation industry, from traffic to airplanes utilization, show a cyclical pattern. Certain variables, however, are of greater significance to the airlines or the manufacturers. Among those, **airline results** are the chief concern of airlines, while **orders** are paramount to the manufacturers. We have therefore decided to focus on these variables, and to emphasize the links between them.

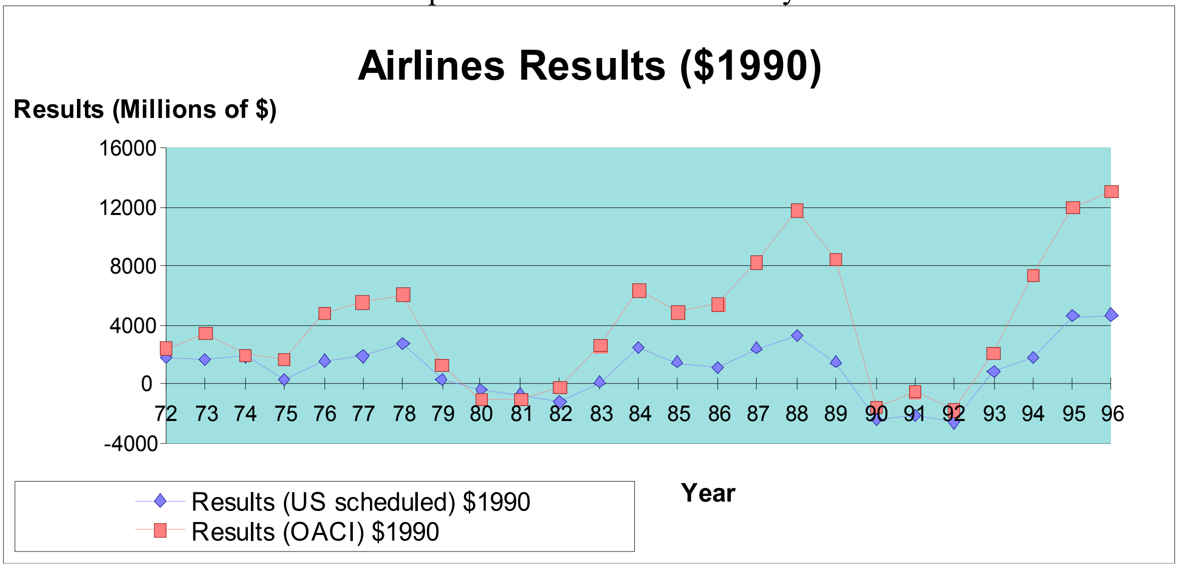
4.2. The manufacturers' cycle

The examination of airlines results shows that cycles are more and more amplified. Results[7] of scheduled US and OACI airlines from 1972 to 1996 , in $1990, are shown in graph 4.1.

Orders (as well as deliveries) are also following a cyclical pattern (see graph 4.2), inducing problems well known to the manufacturers. For instance Boeing had to meet the challenge of increasing its production rhythm from 18 planes a month in 1996 to 43 in spring 1998.

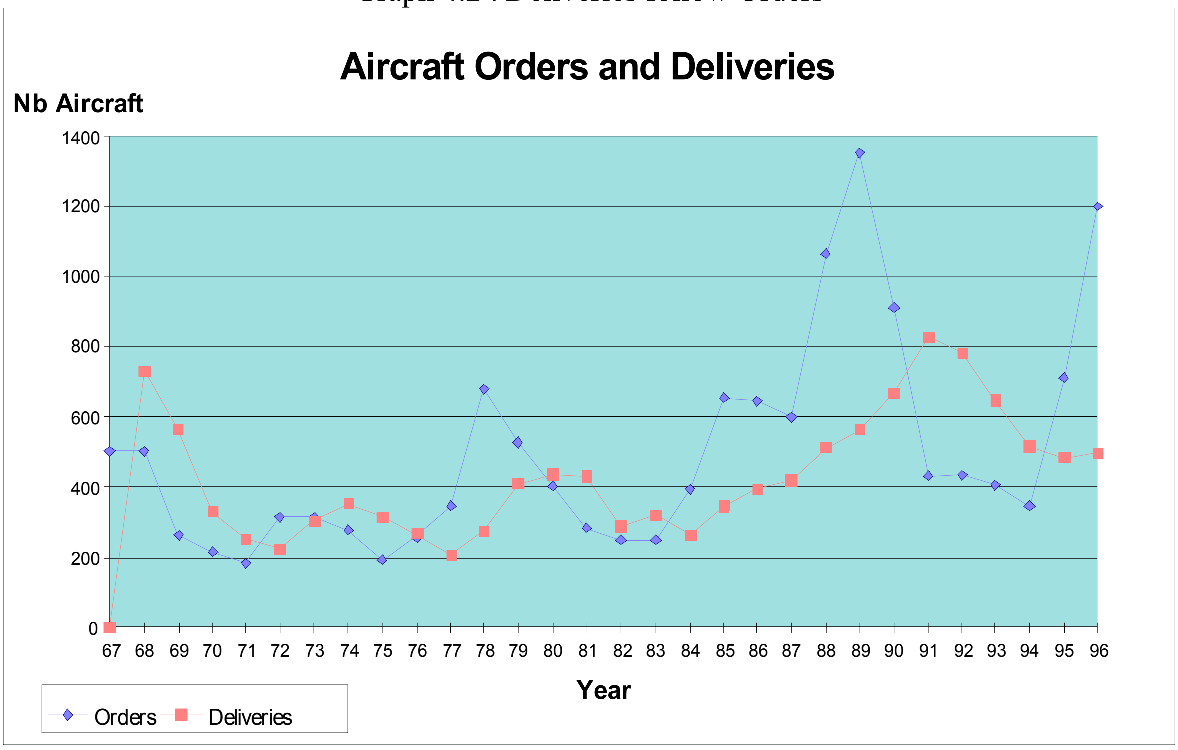
[7] *We chose to use operating results, to avoid distortion*

Graph 4.1 : Airlines Profitability



Sources : ICAO, Walsh Aviation

Graph 4.2 : Deliveries follow Orders



Sources : Walsh Aviation

We computed the correlation between orders and deliveries with different lags, to see how much time there is, on average, between orders (**O_y**) and deliveries(**D_y**).

Table 4.1

Correlation coefficient between Orders and Deliveries			
Lag (years)		**Values**	
0	**Corr(O_y,D_y)**	0,347	
1	**Corr(O_y,D_{y+1})**	0,643	
2	**Corr(O_y,D_{y+2})**	**0,834**	
3	**Corr(O_y,D_{y+3})**	**0,824**	
4	**Corr(O_y,D_{y+4})**	0,494	

Data Source :Walsh Aviation (Data from 1968 to1996)

The correlation between the variables is high when the lag is two or three years (0.82 and 0.83), indicating that on average, it takes the airlines somewhere between two and three years to have airplanes delivered, once ordered.

More interesting and less obvious is the link between results (**P_y**) and orders (**O_y**). The peaks and troughs in orders follow by one year the peaks and troughs in results. The correlation is very high (0.89) and there is a causality easy to understand : most airlines, after a good year, choose to invest in renewing and increasing their fleet.

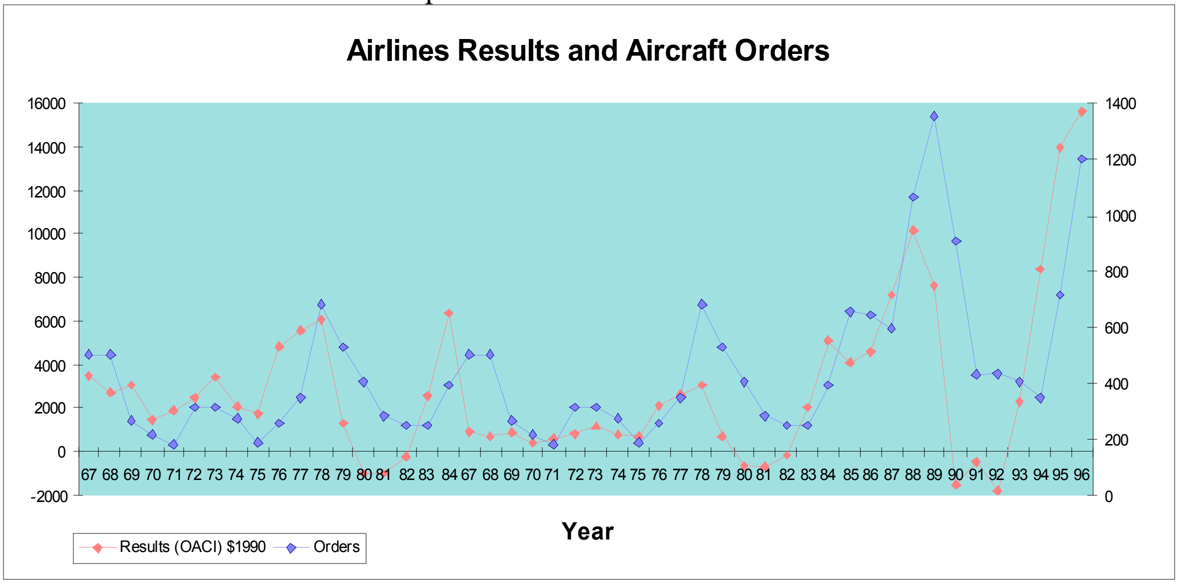
Table 4.2

Correlation between Results and Orders		
Lag		values
0	**Corr(P_y,O_y)**	0,632
1	**Corr(P_y,O_{y+1})**	**0,887**
2	**Corr(P_y,O_{y+2})**	0,754

Data Source :Walsh Aviation, ICAO (Data from 1968 to1996)

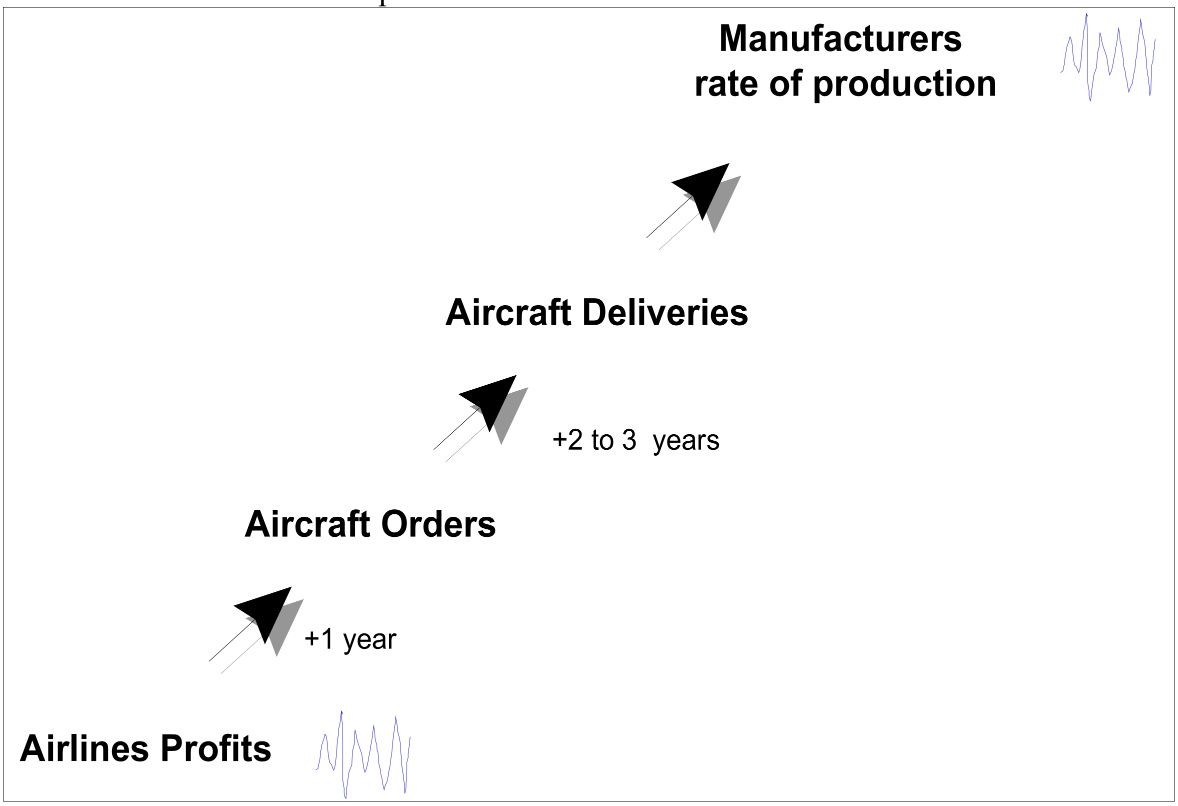
This does not give much time to manufacturers to think ahead and plan their production rhythm, since financial results are only know with certainty towards the end of the year (some years can have good starts but bad endings !). All this explain why manufacturers are mostly forced to follow cycles and have very little influence on their own production rhythm.

Graph 4.3 : Orders follow Profits



These results enable us to draw the first part of the aviation cycle, the one that manufacturers are most interested about, linking airline profits, aircraft orders and deliveries :

Graph 4.4 : The manufacturers « curse »

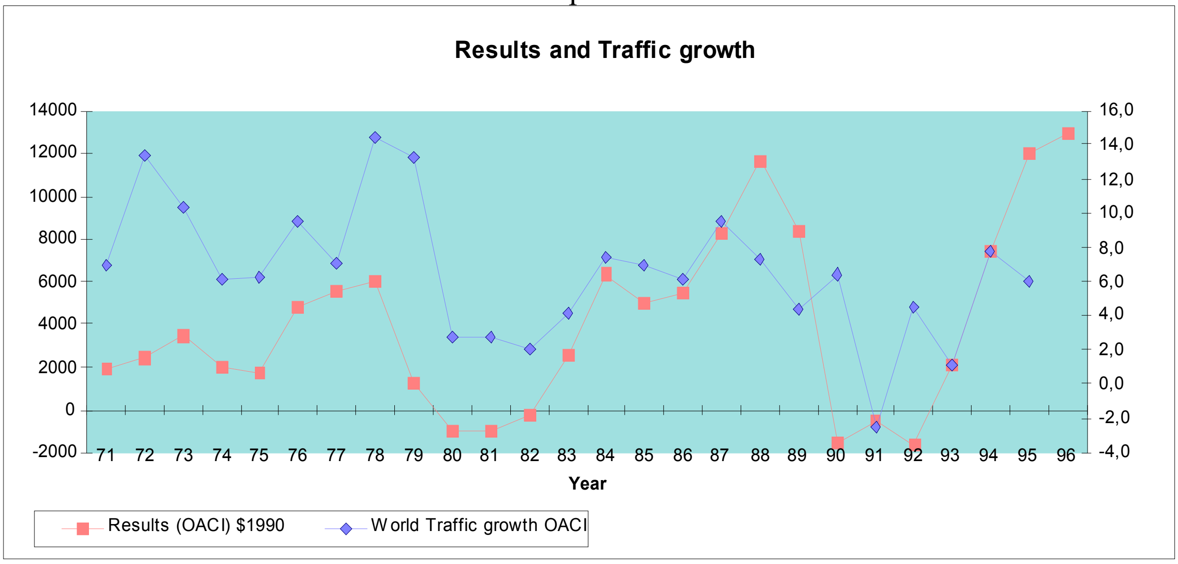


4.3 Airlines profitability cycles

If cycles in airline profits enable us to explain the peaks and trough in orders and deliveries, how can we explain cycles in airlines results ? Where do these cycles come from ?

Contrary to conventional wisdom (see graph 3.1), it is not at all clear that cycles in airlines results originate from cycles in traffic growth. The correlation between results and traffic or traffic growth is weak ($Corr(P_y,,\Delta Traffic_y)=0.34$), and if downturns in traffic are not generally good news in terms of results, high traffic growth does not necessarily mean good results : in 1990 for example, traffic growth is 6.4 percent, and heavy losses (-1500 millions $) are incurred.

Graph 4.5



Therefore, traffic growth is not, by far, the only relevant element in explaining airlines results. Traffic growth is, moreover, not independent on the strategies of the airlines in terms of pricing. If there is over-capacity at one given point, airlines will lower prices in order to regain market shares, and traffic growth will be boosted. In order to look at external determinants of airline results, indicators of economic activity should rather be used.

Internal factors, like investment pattern or pricing patterns, will also affect profitability. Among other variables we could analyze, we found that results are somehow correlated with load factors and deliveries. A high load factor means full planes, indicating that there is no over-capacity. On the other hand, many deliveries in one year create over-capacity and mean low prices and low yields, and therefore poor results.

We estimated a regression model explaining airlines results, and came up with three main statistically significant variables : Economic activity, its variations (GDP and GDP Growth) and Deliveries.

The estimation was made with data from 1979 to 1996. As previous data were available, this is a deliberate choice : modern air transportation began after deregulation occurred and market forces could interact more freely. Before that date, price and route regulation prevented airlines from competing, both on domestic and international level, and therefore, explaining the workings of the industry during that period is a different business.

Table 4.3 : Results as a function of GDP and Deliveries

$$Results = \alpha + \beta \quad \Delta GDP^2 + \gamma \quad GDP + \delta \quad Deliveries$$

Data sources :

Results	ICAO (World Civil Aviation Statistics), Millions USD
GDP[8], ΔGDP	IMF (World Economy Outlook)
Deliveries	Walsh Aviation

Multiple Regression Analysis :

Dependent variable : Results

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	-14886,6	3249,82	-4,58074	0,0004
ΔGDP^2	353,966	90,1992	3,92427	0,0015
GDP	10,4859	1,90444	5,50602	0,0001
Deliveries	-17,8026	4,76903	-3,73296	0,0022

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	3,59273E8	3	1,19758E8	26,18	0,0000
Residual	6,40402E7	14	4,5743E6		
Total (Corr.)	4,23313E8	17			

R-squared = 84,8717 percent
R-squared (adjusted for d.f.) = 81,6299 percent
Standard Error of Est. = 2138,76
Mean absolute error = 1591,5
Durbin-Watson statistic = 1,94988

Sources : ICAO, IMF, Walsh Aviation

This model yields good results. All estimated parameters are statistically significant, and the adjusted R-squared is 81.6 percent. When the model is re-estimated using only the 16 first years, the result of the 17th year (1996) is predicted within 10 percent, showing that the model is stable and could be used for forecasting.

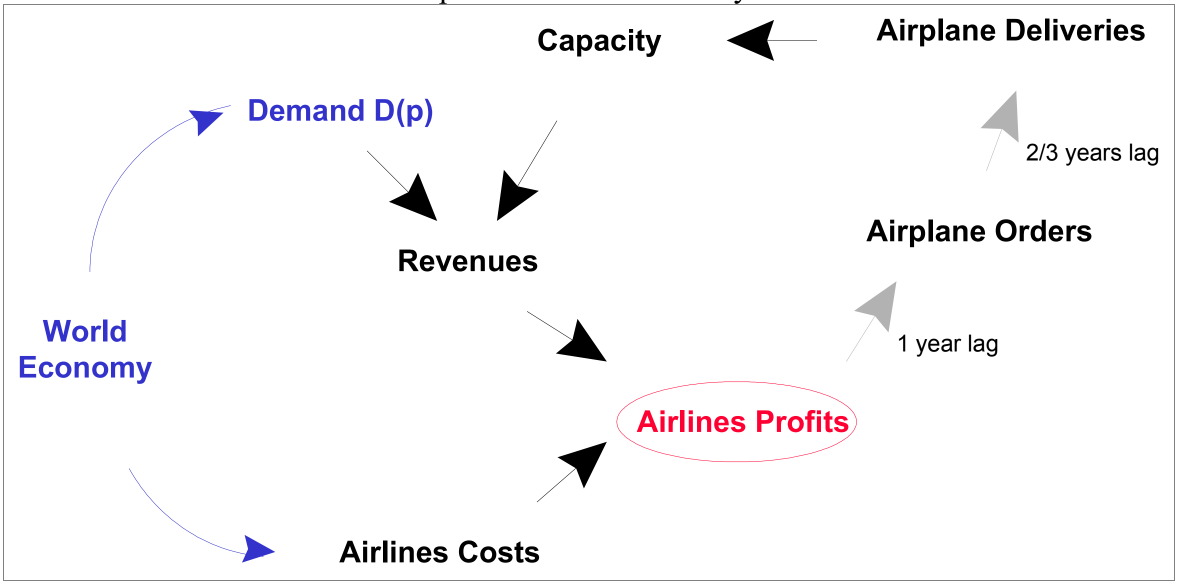
[8] Index 1000 in 1965

The model confirms what could be suspected, i.e. that factors internal to air transportation are important in explaining the airlines profitability. The number of deliveries in one given year is a good indicator of the amount of new capacity that has to be absorbed by the market : is has a negative coefficient, indicating that more capacity means lower prices and lower profitability.

The external factors, summarized by DGP and GDP growth, are also important. The economic conditions are driving demand and have also an influence on costs.

The model, combining internal and external factors, succeeds in explaining the profitability of airlines. It gives us the final clue to the understanding of the airline cycle : Although economic conditions do matter, economic cycles are amplified in the air transportation industry, by the pattern of investment. Good financial results mean orders, resulting in deliveries, very often occurring at odd times, in opposition with the economic conditions. This leads to over-capacity, lower prices in order to maintain market shares, and bad results. As the economy gets better (even in bad years, world GDP growth is always positive, so far !), growing demand gradually absorbs the redundant capacity, and airlines get better. They start investing again....

Graph 4.6 : The Airlines Cycle



Although this description is somehow a simplified presentation of what really happens, it gives a fairly good notion of the causes of cycles, explaining why they are so much more serious in the air transportation industry than in other sectors of the economy.

4.4 Forecasting profitability

Table 4.4 : Profitability forecasting model

$$Results(t) = \alpha + \beta \quad \Delta GDP(t)^2 + \gamma \quad GDP(t) + \delta \quad Orders(t-2)$$

Data sources :

Results OACI (World Civil Aviation Statistics), Millions USD
GDP, ΔGDP FMI (Perspectives de l'Economie Mondiale)
Orders Walsh Aviation

Multiple Regression Analysis :

Dependent variable : Results

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	-12745,9	3980,72	-3,2019	0,0064
Orders(t-2)	-5,41081	2,43044	-2,22627	0,0429
ΔGDP^2	415,601	106,154	3,9151	0,0016
GDP	6,77481	1,7535	3,86359	0,0017

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	3,28936E8	3	1,09645E8	16,27	0,0001
Residual	9,43719E7	14	6,74085E6		
Total (Corr.)	4,23308E8	17			

R-squared = 77,7061 percent
R-squared (adjusted for d.f.) = 72,9288 percent
Standard Error of Est. = 2596,31
Mean absolute error = 2079,85
Durbin-Watson statistic = 1,40952

Sources : ICAO, IMF, Walsh Aviation

In terms of forecasting, more can be done, since we know that the pattern of deliveries is strongly dependent on the pattern of orders. A model can be constructed linking results with economic conditions and previous orders. It gives satisfying results (adjusted R-squared of 72.9 percent), considering that previous orders are a rough estimation of the capacity on the market at a given time.

It enables to make forecasts of airline results depending on one known parameter, the number of orders made two years before (as long as you restrict your forecast to two years ahead, which seems a reasonable thing to do, considering the uncertainty on the economic environment), and one unknown, the economic growth. Depending on hypotheses of economic growth, scenarios can then be elaborated concerning the financial situation of airlines.

5. INVESTMENT AND AIRLINES BEHAVIOR

The airline industry is an oligopoly, which means that there is a limited number of actors in the industry. The behavior of one of them has therefore consequences in terms of pricing and total capacity on the market. The economic analysis of oligopoly (Varian, 1992) points out that behavior of such markets is fairly different from perfectly competitive markets. More specifically, the outcome of competition can lead to non (pareto) optimal situations. Such situations can be explained using models derived from game theory.

Let us imagine a situation where two airlines compete on one market (a route or a set of routes). They have a given market share. Even with correct anticipation of the traffic growth expected on this market (at current prices), it can be shown that the capacity chosen by the airlines will almost surely be superior to the expected traffic growth.

In terms of capacity (seats), each airline can have three strategies :

- increase its capacity on the market by less than the expected growth
- increase its capacity on the market by the same amount as the expected growth
- increase its capacity on the market by more than the expected growth

The first strategy will never be chosen, since it enables your competitor to gain market share over you[9].

The second strategy is a non aggressive one, reasonable as long as your opponent does the same. If he chooses the second strategy, you will loose market share, which is never a good thing.

This can be summarized in a table, choosing simple figures to represent the gains of the airlines.

[9] *We assume that there was no over-capacity in the first place.*

Table 5.1 : A strategic behavior

Airline A / Airline B	**non aggressive strategy (follow market growth)**	**aggressive strategy (invest beyond market growth)**
non aggressive strategy (follow market growth)	g(A) = 2 g(B) = 2	g(A) = -1 g(B) = 3
aggressive strategy (invest beyond market growth)	g(A) = 3 g(B) = -1	g(A) = 1 g(B) = 1

where g(A) and g(B) represent the respective gains of airlines A and B.

In terms of collective welfare, the optimal outcome is {g(A)=2, g(B)=2} since it yield a total gain of 4[10]. It corresponds to each airline matching its capacity increase with traffic growth. They split equally the benefits of increasing demand.

The outcome of both airlines being aggressive is an over-capacity on the market, leading to price cuts, in order to boost demand. Profits go down for each airline : {g(A)=1, g(B)=1}

The outcome of one airline being aggressive while the other is not, is for the aggressive one a large gain, while the other gets less than in any other situation : {g(A)=3, g(B)=-1} or {g(A)=-1, g(B)=3}. It could even be the case that being aggressive when your opponent is not, leads to bigger gains, since with a bigger market share you may be able to raise your prices[11]

In any case, being aggressive is a dominant strategy, since whatever your opponent does, you get more than in the other case (3 or 1, instead of 2 or -1).

This model, known as the « prisoner's dilemma », is very often used to characterize this kind of situations. However simple it may seem, it has a very wide scope, and represents in an adequate way many real situations. We represented a simple case where only two airlines are competing, but it can be successfully generalized to several competitors (Tirole, 1988).

How can the airlines get out of this situation where profits are more or less exhausted by competition ? Again, game theory offers us a way out : if the situation is repeated, then getting along becomes possible. Long term relationships (represented by an infinitely repeated game) enable cooperation. By cooperating, airlines could share the gains from a non aggressive behavior.

This kind of reasoning, however, is only valid in a very stable relationship : competitors have to remain the same all along the game. In the air transportation industry, this is far from the case : existing airlines can disappear (or exit a market) and new airlines can enter a market. If an airline thinks one of its competitors may exit a market as a result of an

[10] *We assume that the consumers' welfare is more or less unchanged in this case*
[11] *In this case the consumers' welfare goes down*

aggressive behavior, it may have as a goal to provoke the exit, and then the framework of repeated games does not hold.

It may not be possible, in this case, to get out of the dilemma. Being aggressive and over-investing may make sense in the long term, in order to eliminate rivals. It may even be in the (short term) interest of consumers, who may benefit from lower prices. In the long term however, exits from markets may lead to monopoly power and need to be watched by regulatory authorities.

6. CONCLUSION : HOW TO SMOOTHE CYCLES

If a tendency to over-capacity, explained by the oligopolistic structure of the airline industry, is worsened by economic conditions, it leads exactly to what we observe : investments timed in good economic periods (when airlines can afford to act aggressively) materialize in the shape of delivered planes (and thus available capacity), a few years later, usually when the economic context is not so favorable (to say the least !). This leads to huge losses (due to a large disequilibrium between supply and demand) and airlines slowly get better when this unbalance is reduced by the growth in demand. Then they start investing again.

To correct this cyclical imbalance between supply and demand, airlines need to adjust in two ways :

First, they should improve their forecasting abilities : although no model can ever predict a demand shock, like the gulf war, a model, like the one we estimated, can be used to build scenarios, and predict how much capacity airlines would want to have in different economic situations and at different points of the economic cycle. This would give airlines boundaries of desirable capacity considering economic conditions and competition. This would help airlines to take advantage of the economic cycles instead of being hit by them, by leading to a better management of capacity.

Since capacity, even managed in a better way, is not as adjustable as airlines would like in order to « ride » the cycles, another important adjustment is to build more flexible capacity. If a fraction of capacity is made flexible, even a marginal one (5 to 10 percent), it may be enough to cope with unexpected changes in demand, since demand can be predicted with reasonable accuracy. For example, capacity can be gained in high demand periods by deferring retirements, or by using short term leases. It can be reduced in low demand periods by returning leased aircraft or retiring old aircraft.

There are important benefits to be gained, for the individual carrier, but also for the industry as a whole, if global capacity matches demand better. This may not be easy to achieve, because it means changing the behavior of all airlines. It will make sense, in order to influence the whole industry, for airlines or groups of airlines to share insights and information concerning the evolution of demand. This may prove a difficult evolution in a very competitive industry, used to the kind of behavior described above, but efforts should be made towards that goal.

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