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How do airlines preferences about engines influence the competition in the commercial aircraft industry: an empirical analysis

Carolina Billitteri and Giovanni Perrone
DTMPIG, Università degli Studi di Palermo,
Viale delle Scienze, Ed. 8, 90128 Palermo, Italy

Abstract

This paper examines the competitive context in the commercial aircraft industry. In particular, the aim of the research here presented is to understand what are the main drivers influencing the choice of a specific engine manufacturer in an aircraft, and how such preferences influence the competition between Airbus and Boeing. In order to do that, we have collected data about the fleet composition of the top 25 airlines and we have located the main drivers influencing the engine configuration in: route specialization, business model and maintenance policy. Implications of such empirical findings in the competition among aircraft manufacturers are finally discussed.

Keywords
Commercial aircraft industry, airlines fleet composition, engine configuration

1. Overview of the commercial aircraft industry and research motivation

Over the last couple of decades, the literature on the aircraft manufacturing industry, particularly on the competition between Airbus and Boeing, has received important contributions.

Many authors reviewed the stages of the competition between the colossals Airbus and Boeing, such as Campos [1] that highlighted how, stage by stage, Airbus has been able to increase its market share basing its success on new technology advance in the design of new aircrafts. Other studies, as Cabral and Kretschmer [2], focused their attention on the birth of the wide-body aircraft market, a relatively new industry segment that dates back to the 1960s. Irwin and Pavcnik [3], instead, examined the rivalry between Airbus and Boeing focusing on the price competition and on the trade dispute in the wide-body aircraft segment.

Otherwise, in recent years, many studies focused their attention on the aircraft manufacturing supply chain, analyzing which are the main suppliers for an aircraft manufacturer and which kind of relationships they establish. In particular, Horng [4] tried to understand the supply chain management strategies and practices pursued by Boeing and Airbus in the 787 Dreamliner and the A380 programs, respectively, in order to identify their long-term strategic implications for supply chain management in the future. A major finding of this research is that both Boeing and Airbus have made their supply chain more collaborative and wider in order to face the development of new innovative products such as the B787, the A380 and the A350. This is quite in line with expectation, since the development of innovative products requires collecting and pooling new knowledge and assets. Moreover, in this research strand, Esposito and Passaro [5] studied the vertical relationships that occur in the aircraft industry between the leader firm and the other firms that take part in the aircraft development; these relationships highlight a complex organisational structure of the sector. The production organisation of this industry develops according to a hierarchical structure including a final assembly area, where the parts and components coming from three sub-sectors (engines, equipment and avionics and airframe). In particular they show how the circulation of information and technology is a crucial factor for supply chain efficiency.

Furthermore, for our purposes is helpful to mention another stream of researches on the aircraft manufacturing industry that is focused on the airlines' fleet composition problem. The core of this kind of researches is on flights schedule problem or on fleet composition. For example, Listes and Dekkery [6] studied this issue and presented a scenario aggregation based approach for determining a robust airline fleet composition that is based on the new concept of dynamic capacity allocation.

Also, some scholars have analysed how airlines preferences determine the aircrafts choice and, therefore, aircraft maker product strategies. For example, the paper of Wei and Hansen [7] reveals that airlines compete and make their strategic choice on fleet composition on the bases of aircraft size and service frequency. Moreover, is particularly

interesting the work of Patterson et al. [8] that highlights how the decision about which engine to use is determined by commercial airline customers, not from the aircraft manufacturer; for this reason, aircrafts manufacturers and engines suppliers must work together closely to design and produce new or complex products, thus they must forge strong and long-term relationships based on considerable levels of trust because of the significant amount of sensitive information sharing required. The authors explain how the relationship itself creates value for both the parties.
However, no significant contributes analyze how preferences and requests on engines from the airlines are characterized, what are the factors that determine such preferences, and how their choice influences the aircrafts manufacturers strategies.
In particular we concentrated our attention only on engine suppliers because engine represents the most knowledge-based, complex and expensive component of an aircraft and because of their strong bargaining power towards aircraft manufacturers. Moreover, also the engine manufacturer industry, as the aircraft manufacturer one, is an oligopolistic industry consisting of three basic players, the Canadian Pratt & Whitney (P&W), the British Rolls-Royce (RR) and the US General Electric (GE), and other three constructors that are joint ventures formed by the players named above and other smaller companies, that are CFM International (CFM), International Aero Engine (IAE) and Engine Alliance (EA).
Furthermore, it is important to underline that engines are very different depending on the characteristics of the aircraft itself and they are components requiring more maintenance. This aspect is very interesting because engines maintenance is characterised by learning curves, so that the most a company is specialized on a specific engine type, the lower the maintenance cost. Under such a perspective, it is quite interesting to see if airlines preferences or requirements towards a specific engine type and manufacturer might influence the competition between Airbus and Boeing.
Therefore, the research question we address in this paper is to analyze how supply relationships in the commercial aircraft industry may be influenced by customers' requirements and preferences. In particular, we wish to investigate how airlines' preferences in terms of engines, can influence the competition between Airbus and Boeing.

2. Market analysis and data collection

Fleet composition choice is one of the most important strategic decisions that airlines have to face, not only because of the huge investment deriving from a new aircraft purchase and the long payback period, but also because this choice affects their operating costs and their strategy in selecting which routes to serve [9]. The challenge in fleet planning is to balance the benefits of a uniform fleet (in terms of same aircraft model and same engine type) and the choice of different aircrafts for different routes [10]. Here it is important to emphasize that our analysis is limited to the large civil aircraft market that typically consists of two product categories: narrow-body and wide-body aircrafts. Obviously, a narrow-body, a medium range and a long-range wide-body are imperfect substitutes for each other, indeed they are designed to serve different markets. Moreover, different planes have significantly disparate purchasing costs and they are used for totally different kind of missions: i.e. a narrow-body 737-600 has about 130 seats and costs about USD 50 million, instead a wide-body 747-400ER can carry up to 500 passengers and costs about USD 230 million [11]. Also, they are used to serve different routes; indeed the first one has flight autonomy with maximum load of 5,500 km and the second one has 14,000 km of autonomy. Beyond the simple distinction between narrow and wide-body, the aircraft manufacturing market is usually divided into several segments on the basis of two main classifications: (i) the maximum range that an aircraft can cover at full load and (ii) the medium number of seats of each airplane. In our work we refer to the first classification that outlines three main segments: short haul (max 3,000 - 4,000 km), medium haul (max 7,000 - 10,000 km) and long haul (max 15,000 - 17,000 km). Furthermore, is also noteworthy emphasizing that the market is characterized by a wide variety of aircraft models and each model is available in several versions: passenger vs. cargo, extended range versions, versions with different length and different number of seats, etc.
Differently from aircraft manufacturers, engine manufacturers are specialized in some specific segments. For example, CFM is specialized only on the short haul niche and more than 80% of the total number of aircrafts in this category, both Airbus's and Boeing's, flight with CFM engines; the only other competitor in this segment is IAE. On the other hand, three main players dominate the long haul segment and they are: GE, RR and P&W, with quite similar market shares, respectively 38%, 26% and 25%.
Thus, in order to answer to our research question, we decided to investigate the fleet composition, from the engine manufacturer point of view, of the biggest airlines worldwide. To detect the sample of our analysis we first examined the airlines market associated to IATA (International Air Transport Association) that covers about the 93% of the world's international scheduled traffic [12].

Then, in order to identify which are the key players in the airlines global market, we followed one of the most common classifications in literature based on the number of passengers carried in one year (2007). We focused on the top 25 airlines worldwide; the reader should note that the estimated total number of passengers travelled by air worldwide in 2007 was 2,25 billion and that the top 25 airlines have carried 1,20 billion of passengers. This means that our sample represents more than 50% of the total population of data.
Our empirical analysis was based on the *Planespotters.net* database. This website offers an extremely large variety of high-quality aircraft information, photos, production lists and detailed airline fleets information. From the *Data Centre* section of the database it is possible to accede to the *Airline Fleet* page and then to the *Airline Index.* By selecting the name of an airline, it appears a table reporting the fleet composition of that carrier. Different types of information are available for each aircraft in the fleet: the construction number of the plane, the aircraft model, the engine type, the delivery date and the aircraft status (*active or stored*). In this work we considered only the aircrafts currently in service (*active*), excluding those ordered but not yet delivered and stored aircrafts.
From this website we have developed a database containing information about 6,312 aircrafts of the top 25 carriers. For each airline we have examined the fleet composition in terms of number of aircrafts of each model and number of models used by each company; for each aircraft model it was also reported what is the engine manufacturer and engine model, with the exception of some planes for which this information was not available.
Just to give an idea of the market competition, Table 1 reports the number of Airbus/Boeing aircrafts actually used by the top 25 carriers and the relative market shares.

Table 1: Aircraft manufacturers market shares in the top 25 airlines

	Airbus	Boeing	Others	Tot
N° of aircrafts	1,912	3,748	652	6,312
Market Share	30.3%	59.4%	10.3%	100%

Moreover, it is particularly interesting for the purpose of the research to examine what is the market distribution of the engine manufacturers. Such data are reported in Table 2. As the reader can notice CFM International is leader of the market with a market share of 45% and this is because of its leadership in the largest segment, the short haul one.

Table 2: Engine manufacturers market shares in the top 25 airlines

	CFM	GE	P&W	RR	IAE	AE	unknown	Tot
N° of aircrafts	2,871	896	1,299	615	415	4	212	6,312
Market Share	45.48%	14.19%	20.57%	9.74%	6.57%	0.06%	3.37%	100%

3. Research question assessment and hypotheses developed

As previously mentioned, main objective of this work is to respond to the following research questions: *What are the issues, if any, driving airlines companies' preference toward a specific engine configuration when buying a new aircraft and how such preferences influence the competition between aircraft manufacturers?* In order to answer to the first part of the research questions, we analyze first the fleet's composition of the major airlines, trying to bring out what are their preferences towards engine manufacturers and to highlight main drivers influencing fleet composition.
In developing the empirical analysis we started classifying the top 25 carriers on the basis of engine manufacturers concentration. In order to do that, by using the collected data, we have classified airlines in three classes: 1) High concentrated airlines: this first group includes those companies having more than 75% of the fleet flying with engines of the same manufacturer; therefore, such airlines have a strong preference towards a specific engine manufacturer. They are: Southwest Airlines, Ryanair, EasyJet and Air Berlin; 2) Medium concentrated airlines: this group includes those carriers having at least the 50% of the fleet with the same engine manufacturer; these airlines seem to have a preference for a specific engine manufacturer, but no so strong like the first one. They are: Air France-KLM, Northwest Airlines, Lufthansa, Japan Airlines Group, All Nippon Airways, China Eastern Airlines, Air China, Emirates Airline, Korean Air Lines, Continental Airlines, Delta Air Lines, United Airlines and Iberia; 3) Low concentrated airlines: This group consists of those airlines that do not seem to have a clear preference towards a particular engine configuration and therefore have a mixed and variegated fleet (less than 50% of the fleet uses the same engine). They are: American Airlines, China Southern Airlines, US Airways, British Airways, Air Canada, Alitalia, Qantas, SAS Group.
By analyzing the characteristics of each company within each group, their business models, their visions and statements of CEOs about their business strategies published in the companies websites we started to identify common aspects within each group.

A first dimension that has been investigated concerns the type of market the airlines are focused on, that is: regional, national or intercontinental. Indeed, the different market focus of a company determines a different fleet composition; namely, if a carrier has a regional focus, thus it covers short distances, certainly it will have a fleet composed only by short haul aircrafts and, as anticipated, in the short haul segment the engine choice is restricted to CFM or IAE engines. On the other hand, if a company has not a focus on a specific segment, but it flies over short, medium and long distances, its fleet will have a lower concentration on the engine point of view.

So by matching literature analysis on fleet composition [10, 13] and engine concentration analysis developed in this paper we have formulated the following hypothesis:

Hypothesis 1: The greater the focus of an airline on a particular segment (i.e. short-haul), the greater the likelihood to have a high concentration on an engine manufacturing company.

Moreover, the strategic choice of fleet composition is obviously related with the carrier's business vision; namely, low cost airlines have different strategic objectives than flag/national airlines. Thus, a low cost carrier generally offers low fares; for this reason, one of the main business model practices of a low cost company is to have a standardized fleet, composed by a single type of airplane (commonly short haul aircrafts, the Airbus A320's or Boeing 737's families), with the same engine type (CFM or IAE engines), in order to obtain a better flexibility of the crews' assignment and to generate savings in training, qualification and stock of spare parts [14]. Therefore, matching again literature analysis on fleet composition in relation to airlines business model [14] and engine concentration analysis here developed we have formulated the following hypothesis:

Hypothesis 2: Low cost carriers will have a higher concentration of the same engine manufacturer compared to flag airlines.

Finally, we have hypothesized that another key factor in the engine choice may depends on how each company performs engines maintenance, that is, if it is done in-house or outsourced. This is a crucial point because engine maintenance tends to be the most expensive type of all the MRO activities of an airline company [15]. Moreover, when a company decides to make all MRO services internally, it is forced to specialize in the maintenance of each engine model and this means suffering higher costs, as there are many models of engines in the fleet. Indeed, engine maintenance is an activity subjected to high learning economies; therefore companies prefer to specialize on a single manufacturer when they perform maintenance internally. On the other hand, when an airline decides to outsource the engine maintenance, it concludes a contract with a specialized company (generally one contract for each engine type/manufacturer maintenance) that, by collecting orders from different airlines, can gain learning economies on different engine types, developing lower costs for any kind of engine. For this reason a company outsourcing the maintenance of its engines should have a more diversified fleet than one that performs MRO services in-house. According to such reasoning, the following hypothesis has been formulated:

Hypothesis3: The greater the outsourcing propensity of an airline company, the lower the likelihood to have a high concentration on an engine manufacturing company.

4. Empirical analysis, discussion and conclusion

In order to test our hypotheses, we used a multiple regression model. Our dependent variable, *the engine manufacturer concentration of each airline* that will be indicated with C is a number in the interval [0, 1] and it expresses the highest percentage of the same engine manufacturer (i.e. the leader on that company) within the company fleet. Therefore, the closer to 1 is C, the highly concentrated is the company's fleet on a single engine manufacturer.

In order to test the first hypothesis, we have considered two variables expressing fleet concentration on *short haul (SH)* and on *long haul (LH)* niches, that is the percentage of company's aircrafts belonging to the two segments. Of course, we have not included the percentage in the medium haul segment, because it will be correlated with the other two variables. Also these two variables are continuously varying in the [0, 1] interval.

Moreover, in order to test the second and third hypotheses we detected, through the database described above, the airlines' market orientation and the maintenance policy; for this purpose, we have used two dummies variables: the first, namely the *market orientation (MO)*, indicates whether an airline is a low cost (MO = 1) or a flag one (MO = 0); the second one, namely the *outsourcing (Out)*, indicates whether an airline outsources the engine maintenance (Out = 1) or it performs it internally (Out = 0). Table 3 reports the top 25 airlines ranked by the number of passengers carried in 2007 and the data used in the regression analysis.

Table 3: Top 25 Airlines Ranking and data used in the regression analysis

Rank	Airlines	N° of passengers 2007 (M)	Fleet dimension 2007	Main Engine Manufacturer in the fleet	*C*	*SH*	*LH*	*MO*	*Out*
1	Southwest Airlines	101,911	543	CFM	1.00	1.00	0.00	1	1
2	American Airlines	98,162	644	P&W	0.46	0.12	0.07	0	0
3	Air France-KLM	74,795	381	CFM	0.59	0.54	0.46	0	0
4	Delta Air Lines	72,9	446	P&W	0.61	0.17	0.03	0	0
5	United Airlines	68,4	349	P&W	0.60	0.40	0.22	0	0
6	Lufthansa	62,9	251	CFM	0.58	0.60	0.38	0	0
7	China Southern	56,9	268	CFM	0.36	0.63	0.10	0	1
8	US Airways	54	347	CFM	0.49	0.82	0.03	0	1
9	Northwest Airlines	53,7	244	CFM	0.52	0.52	0.23	0	1
10	Japan Airlines Group	50,442	206	P&W	0.64	0.05	0.46	0	0
11	All Nippon Airways	50,384	177	GE	0.51	0.33	0.34	0	1
12	Ryanair	49	174	CFM	1.00	1.00	0.00	1	1
13	Continental Airlines	46,2	358	CFM	0.72	0.72	0.06	0	0
14	SAS Group	41,1	108	CFM	0.44	0.49	0.10	0	0
15	China Eastern Airlines	39,161	210	CFM	0.60	0.80	0.14	0	1
16	Air China	37,256	233	CFM	0.68	0.70	0.20	0	0
17	EasyJet	37,2	158	CFM	0.94	1.00	0.00	1	1
18	British Airways	33,06	231	RR	0.44	0.44	0.43	0	1
19	Air Canada	31,5	194	GE	0.42	0.41	0.13	0	1
20	Air Berlin	27,9	126	CFM	0.85	0.93	0.06	1	1
21	Iberia	26,9	147	CFM	0.74	0.60	0.22	0	0
22	Alitalia	26,9	118	CFM	0.42	0.42	0.08	0	0
23	Qantas	25,243	140	GE	0.44	0.40	0.39	0	0
24	Korean Air Lines	22,353	127	P&W	0.65	0.25	0.68	0	0
25	Emirates Airline	20,448	132	RR	0.54	0.00	0.99	0	1

An Ordinary Least Squares (OLS) multiple regression analysis has been conducted over the data depicted in Table 3 by using the Gretl® statistical package. The results have been tested for verifying that all the basic assumptions for linear regression models were satisfied. The White test against heteroskedasticity has resulted significant, so that a weighted OLS corrected for heteroskedasticity linear regression model has been applied. The regression results, reported in Table 4, show how the model is able to predict the value of the dependent variable given that corrected R-square is equal to 0.878.

Note that p-levels are lower than 0.10 for all the variables; particularly *long haul*, *market orientation* and *outsourcing* have significant coefficients lower than 0.05, indicating that they are the factors better explaining the dependent variable.

Table 4: Regression analysis results

Hypothesis 1				Hypothesis 2		Hypothesis 3	
Short Haul		Long Haul		Market Orientation		Outsourcing	
Coef.	Sig.	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.
0.214	0.052*	0.216	0.023**	0.420	0.000***	-0.128	0.004***

***$p<0.01$; **$p<0.05$; *$p<0.10$

As the reader can notice, the model results confirm all our hypotheses; the hypothesis 2 is confirmed by the fact that the independent variable *market orientation* has a positive coefficient (0.420) with the dependent one, meaning that low cost airlines have a greater tendency to have a fleet concentrated in terms of engines.

Instead the independent variable *outsourcing* is negatively correlated, although lightly, with the dependent one (-0.128), and this supports the hypothesis 3: companies outsourcing the maintenance are those having a more variegated fleet.

Finally, also hypothesis 1 is confirmed; indeed, the coefficients for variables *short haul* and *long haul* are respectively 0.214 and 0.216, indicating that the more an airline focuses on a specific route (short or long), the more concentrated is its fleet in terms of engines from the same manufacturer.
The empirical analysis clarifies the first part of our research question, that is airlines aircraft choice depends also on the engine manufacturer. Indeed, we have demonstrated that airlines focus on a specific segment, their business model and the maintenance policy adopted influence on the choice of the engine manufacturer, meaning that airlines have specific preferences toward an engine configuration.
These results are also important to address the second part of our research question that is the impact of these preferences on competition between the aircraft manufacturers. Indeed, from such a result emerges that if Airbus and Boeing want to compete in the market for low-cost airlines, they must necessarily have relationships with CFM that is the segment leader. As matter of fact, it is not a coincidence that the formation of IAE joint venture has been conducted to mitigate the excessive power of CFM in the short haul segment; indeed, the reader must note that CFM is a JV formed for the 50% by GE; instead IAE was formed subsequently by four big companies including P&W and RR that wanted to entry in the market for small engines.
Moreover, from our analysis we have noted that in the medium and long haul segments, both Airbus and Boeing allow the airline companies to choose between different possible engine configurations, namely the same aircraft is available with two or even three engine types of different manufacturers. Obviously this implies higher development costs for both companies, since the design of aircrafts and engines is joined; but it represents a necessary investment since they want to maintain all airlines as possible customers. Thus, it is very important for both firms to have relationships and sign collaborative development agreements with different engine manufacturers; this increases the engine manufacturers bargaining power and enhances the competition between Airbus and Boeing.

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