Examination of cost-efficient aircraft fleets using empirical operation data in US aviation markets

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ABSTRACT

Efficient fleet configuration is a critical problem for air carrier management. This study is primarily concerned with average operating costs and examines the optimal fleet adapted to numerous flight routes longer than 1000 nautical miles. An aircraft-specific operating cost model is derived to estimate market average direct operating costs (DOC) of 22 aircraft types operated by 22 US airlines. It is used as a base in a fleet configuration optimization model to figure out the variability of optimal fleets for segment markets of varying sizes and lengths as well as in response to the dynamics of market circumstances. While recognizing the superior fuel burn performance of narrow-body aircraft such as Boeing 737 and Airbus A320 series, we find operating cost efficiency of wide-body aircraft (B777 and A330 series) due to the economies of scale in the non-fuel operating costs associated with aircraft size. There is a possible reduction of DOC by substituting the wide-body aircraft for smaller ones that are dominant in the current US domestic markets. And the cost efficiency of the wide-body fleet is more robust in dense and longer distance markets (particularly longer than 2000NM), especially considering fuel price fluctuations. Finally, the optimal fleet analysis with empirical traffic data suggests a mixed-size aircraft fleet, configured with narrow- and wide-body aircraft, as an alternative for a wide range of segment markets that vary in size and length.

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1. Introduction

This study is primarily concerned with average operating costs of various aircraft types in the US aviation markets, and examines cost-efficient fleets and their operational patterns for medium- and long-haul routes in a macroscopic view. In the aviation sector, aircraft fleet configuration is a complex problem that must adapt to numerous factors such as financial and operating performance of aircraft, networking and operation strategies of airlines, in addition to the dynamics of local and global market circumstances. Airlines can adopt distinctive strategies on the choice of aircraft that vary in capacity and flight range. For example, not a single US airline has ordered the Airbus A380 (506 seats in a three-class layout of China Southern Airlines), which contrasts with the major airlines in East Asian countries (Bloomberg, 2015). In the US aviation markets (>1000 Nautical Miles, NM), a common preference is observed toward small- and medium-size aircraft as four narrow-body types (B737-700, B737-800, A320-100, and B757-200) account for 67% of the market total operations in Q2 2012 – Q1 2013. Operating the bulk of international long-haul routes, on the other hand, wide-body types are used in a limited way in the domestic markets connecting major hubs (e.g. B747-400 in Seattle - Detroit).

In contrast to the empirical observations above, there is a disparity in the air transportation literature, regarding the size of cost-efficient aircraft. Many studies identify the small economic efficiency of wide-body aircraft (B777 and A330 series) due to the economies of scale in the non-fuel operating costs associated with aircraft size. There is a possible reduction of DOC by substituting the wide-body aircraft for smaller ones that are dominant in the current US domestic markets. And the cost efficiency of the wide-body fleet is more robust in dense and longer distance markets (particularly longer than 2000NM), especially considering fuel price fluctuations. Finally, the optimal fleet analysis with empirical traffic data suggests a mixed-size aircraft fleet, configured with narrow- and wide-body aircraft, as an alternative for a wide range of segment markets that vary in size and length.
(Ryerson and Hansen, 2013). This issue even appears in the aircraft industry as shown in the contrasting future plans of Boeing and Airbus that have launched the Dreamliner Boeing 787 (wide-body less than 300 seats) and super-sized Airbus A380 for long-haul markets respectively (The Guardian, 2013).

The argument above emphasizes the complexity of airlines’ fleet configuration reality which causes the gaps from the literature.1 Among the variety of internal- and external factors bearing on the problem, we focus on aircraft operating costs in a market average, even though recognizing that it is not the only factor in practice. The goal is to identify the variability of cost-efficient aircraft not only by segment-market size and length but also in response to varying operational restrictions as proxies for market dynamics. A cost minimizing optimization problem is employed with operational constraints to examine impacts of those factors on the choice of optimal aircraft types and their operation pattern. The characteristics of the resulting optimal fleets are further compared to those of empirical fleets observed in the US markets, which provide useful insights and an understanding of the dominance of some narrow-body types at a fresh point of view of cost optimization.

2. Background

2.1. Core issues on the aircraft fleet operations

With the rapid growth of air traffic, balancing aircraft operations with infrastructure capabilities is an important issue due to the increasing costs associated with airport (and aerial) congestion (Takebayashi, 2011). In 2007, the Federal Aviation Administration (FAA) estimated that the flight delays cost the US aviation industry $8 billion, much of it due to increased spending on crews, fuel, and maintenance (Ball et al., 2010). In spite of possible reduction of the delays through utilizing larger size aircraft, many authors rationalize the airlines’ operational preference toward smaller aircraft as follows: (1) in a competitive market environment airlines can increase their service frequency by using smaller aircraft, possibly reducing passengers’ schedule delay (Givoni and Rietveld, 2009); (2) they are perhaps less in favor of the decreasing returns of upsizing their fleets resulting from increases of the costs (Wei and Hansen, 2003); and (3) the existing technological gap between narrow- and wide-body types (Peeters et al., 2001). One concern in this paper is to explore those operational inferences in the optimization problem for aircraft fleet configuration, through manipulating its constraints for balancing maximum and minimum flight frequencies given for individual segment markets.

Market dynamics also matter in the aircraft choice of airlines. As a substantial component of the operating costs, jet fuel price has shown large fluctuations affected by a wide range of external factors such as the three-fold increase of oil prices during the economic recession (Chao and Hsu, 2014). There are contrasting expectations of optimal aircraft size under such fuel price increases that possibly lead to: (1) more utilization of large aircraft for commercial passenger markets (Givoni and Rietveld, 2009) and air cargo markets (Chao and Hsu, 2014), and (2) a reduction in aircraft size even though aircraft sizes of current operating fleets in the US are smaller than optimal (Ryerson and Hansen, 2013). We deal with this issue through observing variations of optimal aircraft choices adapting to incremental fuel prices, which in turn allows us to infer the leverage of fuel price fluctuation in current fleet operation practices.

In those debates on efficient aircraft type and size, the aircraft operating cost performance is a key factor to assess airline fleets in the current markets such as the operational indicators like average cost per available seat miles (ASMs), revenue passenger miles (RPMs) (Babikian et al., 2002; Lee et al., 2001; Tsoukalas et al., 2008). Cobb-Douglas and translog models are also used to figure out key attributes and their relationships in determining the cost at the entire market level (Ryerson and Hansen, 2013; Wei and Hansen, 2003). However, less attention has been given to the possible alternatives and their relative efficiencies for a wide range of routes with different conditions. To tackle this, an empirical data based cost function is estimated to measure aircraft-specific average operating costs, which is then employed as an objective of the optimization problem. Various forms of aviation related data are utilized, including air carrier financial reports (P-5.2) and traffic statistics (T2) in Form 41 of the BTS, and EMEP/EEA aviation inventory of the European Environment Agency (EEA). Characteristics of the aircraft operating costs with their empirical data used in this paper are specified in the next section.

2.2. Operating costs and empirical data in the US

Operating costs of airlines are composed of various cost terms. Form 41 financial reports in the US provide the costs classified into two main functional groups: direct and indirect operating costs. The direct operating costs (DOC) include aircraft operating expenses that are further classified into three subgroups: (1) flying operations costs including pilot salary2 and fuel; (2) maintenance of flight equipment; and, (3) depreciation (and amortization) of flight equipment. On the other hand, indirect operating costs (IOC) include all other expenses, not directly related to the aircraft operations, such as passenger service expense (e.g. flight attendants, food), aircraft servicing expense (e.g. line servicing, control, landing fees), traffic servicing, advertising, reservation and sales expenses. Note that since the data report the IOC terms at the airline level, not at the aircraft-specific level, it is hard to match the costs with particular aircraft types. In line with Wei and Hansen (2003), therefore, we develop a cost function for DOC, which accounts for about 55% of an airline’s entire budget in general (Lee et al., 2001).

One limitation associated with P-5.2 is the difficulty utilizing the highly aggregated cost data, collected by [airline (c), aircraft type (k), operating region (r), quarter (and year, t)], for a disaggregated analysis (Swan and Adler, 2006). Since the data include insufficient traffic related attributes, furthermore, it is limited to matching the statistics with traffic data (e.g. T100 segment traffic) and further investigating the operating costs at individual segment market level.3 To deal with the data for aircraft performance assessment, joining P-5.2 with US Air Carrier Traffic Statistics (T2), which summarizes the segment traffic attributes in T100 by (c,k,r,t), is an effective way that enables us to expand applicability of the financial data with various traffic based metrics (e.g. ASMs, RPMs, and departures), illustrated in previous studies (Babikian et al., 2002; Lee et al., 2001). These two databases share the three key attributes (see the grey box in Fig. 1) which exactly correspond with each other.

We collected (and joined) both of P-5.2 and T2 for 2010–2014 for 22 aircraft types4 of 15 US major airlines which account for 98% of traffic in the markets (>1000NM) for Q2 2012 – Q1 2013. A total of 2639 records were obtained after omitting some irregular cases.

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1 Further reading material is in the following: O’Kelly (2014), Vasigh et al. (2012).
2 Other crew salaries are not accounted for in P-5.2.
3 There is also an issue with the ambiguity of the operating region definitions as the Domestic category further includes aircraft operations with Canada.
4 In our study, Boeing 787 and A380 series are not considered because of their insufficient records in the empirical data.
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