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An empirical model of airline fleet standardization in Brazil: Assessing the dynamic impacts of mergers with an events study

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This paper develops an empirical model to investigate the strategic fleet management practices in the air transport industry regarding airline fleet standardization (AFS). We conduct an econometric analysis of the key drivers of AFS in Brazil and study the dynamic effects of five merger events. We find evidence of a significant drop in AFS following most of the consolidations, which is gradually reversed during the post-merger integration efforts. Additionally, except for the major full-service carrier, all other airlines had an estimated overall trend toward more intense fleet standardization over the entire period, revealing a stronger preference for seeking cost competitiveness over market opportunity when facing competition in the market.

1. Introduction

This paper empirically investigates the practice of reducing aircraft types by airlines, namely airline fleet standardization (AFS). One of the most important roles of fleet management in the modern airline industry is related to aircraft acquisition oriented to gaining a competitive advantage in the market.[1] An airline can add airplanes to (or remove airplanes from) its current fleet based on the expected dynamics of demand, costs, and competition conditions. When performing strategic fleet management, airlines trade off between cost competitiveness – through increased fleet standardization – and market opportunity – through increased fleet diversification. On the one hand, carriers must reduce the number of aircraft types in their fleets to control costs associated with pilot and mechanic training, line servicing, ground equipment, and aircraft, airframe, and engine inventories. On the other hand, airlines typically must expand through the addition of new missions and, consequently, to increase the diversity of their portfolio of served markets. By adding new routes and destinations, a possible outcome is an increase in the variety of aircraft types in the air fleet. Exploiting market opportunities may then give rise to the effect of adding complexity – and its associated costs – to the existing network structure of carriers (Holloway, 2008).

As a consequence, the sequence of capacity adjustments performed by an airline over time is driven not only by industry expectations regarding overall traffic growth but also by a deliberate tuning in fleet size and composition targeting a better positioning with respect to competitors in the market. In other words, strategic fleet management may be performed through a dynamic set of fleet standardization levels by carriers. The management of airline fleet standardization (AFS) indicators, however, can only be accomplished within certain limits and is often accomplished only in the medium-to-long term. In fact, the delivery of a new aircraft resulting in an addition to a carrier's current fleet is typically possible only with a time lag. In contrast, an airline may obtain significant fleet management flexibility by leasing an aircraft to meet short-term demand variations at the cost of higher disbursements of leasing payments.

In the context of competition in the airline industry, AFS levels have increased in importance over the last decades as a key strategy to

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[1] See, for example, "If Southwest wanted to acquire another airline, which would it target?", Dallas Business Journal, available at www.bizjournals.com, November 4, 2019. "Is it safe to assume that if the board is debating a second fleet type, as you said today, it's also debating consolidation? Or, is it somehow possible to divorce those two topics? Because in my mind, they're highly intertwined." - asked Jamie Baker (JP Morgan analyst). "They are potentially intertwined, but they could also be disaggregated." - answered Gary Kelly (chairman and chief executive of Southwest Airlines).

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enhance the efficiency of flight operations. Cost competitiveness has become an important element for airlines due to the enhanced price competition that has prevailed since regulatory liberalization. In fact, enhancing AFS has become more widespread, especially with the entry of new operators based on low-cost carrier (LCC) standards. More recently, the focus on competitive strategies has been intensified with the need to stimulate new demand aimed at producing higher ancillary revenues. These and other market challenges have led to the emergence of different airline business models. Traditionally, fleet standardization has been associated with the LCC business model created by Southwest Airlines in the US airline market. In fact, that company is currently one of the world's largest airlines operating with a highly standardized fleet of aircraft based on the Boeing 737 family. Other major LCCs around the world, such as EasyJet and Ryanair in Europe have adopted similar homogeneous fleet configurations.

In tandem with the emergence of AFS as a vital element of the LCC business model, the existing Full-Service Carriers (FSCs) have notably improved their operating performances through market survival strategies in an attempt to compete with the LCCs. In particular, some of the FSCs have resorted to fleet compositions marked by fewer models, families and aircraft manufacturers. In fact, fleet standardization has become a major operational issue for large airlines around the world. For example, in 2018, the major European FSCs Lufthansa and SAS Scandinavian Airlines announced aggressive plans toward their fleets' higher aircraft family and manufacturer standardization – the former will have an all-Airbus fleet and the latter is committed to a standardized fleet of Airbus A320s for all the group's deliveries beginning in 2019.[2] In 2016, United Continental released a new fleet plan retiring many of its regional aircraft and increasing its Boeing 737 family participation in the fleet from 25% to 26.5%.[3] Meanwhile, Southwest Airlines retained its fleet management strategy through the sale to Delta Airlines of the B717s from its acquisition of AirTran, aiming to maximize its fleet standardization toward the B737 family of aircraft that has characterized its operations for decades.[4]

A new element of complexity has been recently added to the "standardization–diversification trade-off" problem typically faced by airlines, however. With the advent of the complications stemming from Boeing and its clients relative to the grounding of the 737 MAX aircraft by aviation authorities, airlines have become more conscious of the manufacturer-related risks associated with a fully (or highly) standardized fleet. When strictly confined to a few aircraft models and a single manufacturer, the strategic fleet planning of a carrier is exposed not only to traditional risks, such as possible delays to planned aircraft deliveries, but also to crucial manufacturer-specific safety issues that may turn into uncontrollable events, creating negative public perception and/or failure to meet demand with adequate capacity. It has become clear that the manufacturer's reputational risk is now a key element for the modern strategic fleet management of any airline worldwide. Even Southwest Airlines, which pioneered the fleet standardization strategy, has started to rethink its fleet planning mantra since the 737 MAX groundings.[5]

The present paper develops econometric modeling to inspect some of the decision-making criteria that carriers utilize when setting their AFS levels. We consider the Brazilian airline industry of the 2000s and 2010s as a case study. Our analysis of the drivers of AFS aims to investigate the market circumstances that lead airlines to either increase, maintain or reduce the degree of their fleet standardization at the aircraft model level. Our study builds upon Zou et al. (2015) and employs the Herfindahl-Hirschman Index (HHI) to assess AFS. We contribute to the literature by extending the approach of previous studies that have addressed the issue of the consequences of AFS: Borges Pan and Espírito Santo (2004), Kilpi (2007), West and Bradley (2008), Brüggen and Klose (2010), Merkert and Hensher (2011), Zuidberg (2014), and Zou et al. (2015). To the best of our knowledge, our study is the first to consider AFS as a dependent variable in an econometric framework, and thus to consider fleet standardization as a manageable market weapon within a broader strategic fleet planning configuration, while aiming at estimating the motivating factors behind AFS decision-making. We also extend the airline merger literature by considering the impact of five airline merger events, and the dynamics of adjustment in the post-merger integration period, on the fleet adjustments of airlines over time.

This paper is divided as follows. Section 2 presents the discussion of the literature on fleet standardization in the airline industry. Section 3 presents the research design, including a discussion of the empirical model of determinants of fleet standardization in the Brazilian airline industry. Section 4 presents the estimation results and discussions. Section 5 discusses robustness checks. Lastly, Section 6 presents the conclusions.

2. Fleet standardization in the airline industry

In the modern air transport industry, it is critical for an airline to appropriately set its level of fleet standardization. Through this configuration, a company can decide on the diversification of its fleet over a strategic horizon. The choice between standardizing and diversifying its fleet reveals an important trade-off in corporate fleet planning because it is a key driver of cost competitiveness and the ability to serve routes in a variety of markets, especially those with diverse characteristics. The larger the portfolio of routes served by the carrier, the greater its fleet diversification should be. However, with diversification, airlines cannot take advantage of the fleet commonality features present in most aircraft families. Therefore, properly setting the level of fleet standardization is a key strategic element of market positioning in modern, deregulated air transport markets.

2.1. Fleet standardization and fleet commonality

There is a conceptual difference between fleet standardization and fleet commonality, as discussed by Brüggen and Klose (2010). Fleet standardization refers to the homogeneity of the fleet in terms of the number of aircraft manufacturers (e.g., Boeing), families (e.g., Boeing 737) and models (e.g., Boeing 737–900). A completely standardized fleet would comprise a single aircraft model, whereas a less standardized fleet would comprise several aircraft models. Fleet commonality, on the other hand, is related to the shared characteristics of aircraft in a fleet, such as similar components, shared spare parts, and crew interchangeability. Aircraft manufacturers often use 'fleet commonality' to suggest the interchangeability of parts and pilots among its aircraft model products. Thus, it is quite common for aircraft models from the same family to provide benefits from greater fleet commonality for airlines. However, there is no guarantee that a completely standardized fleet possesses perfect fleet commonality. For example, a hypothetical fleet of 20 Airbus A320s may comprise aircraft equipped with different engines, such as the CFM 56 and the IAE V2500. Therefore, the degree of commonality observed in this fleet varies depending on how these aircraft are powered. In contrast, when more than one aircraft model or family utilize the same component type, the opposite situation may arise, namely, that fleet commonality might still be present even in a non-standardized fleet.

Borges Pan and Espírito Santo (2004) suggest two indexes to assess

[2] "Lufthansa Group to standardize A320 fleet", available at www.businesstraveller.com, January 26, 2018. "SAS Goes All-Airbus", available at *airlinerworld.com*, April 10, 2018.

[3] "What Is United Continental's New Fleet Plan?", available at www.forbes.com, October 10, 2016.

[4] "Southwest's Fleet Initiatives Are Helping Preserve Its Low-Cost Advantage", available at www.forbes.com, February 28, 2014.

[5] "Boeing's Woes Can Get Worse. Just Ask This CEO", available at *bloomberg.com*, October 25, 2019.

the similarities between the aircraft in a fleet. The cell standardization index refers to the standardization of airplanes' cells (i.e., airframes), while the powerplant standardization index refers to the standardization of airplanes' powerplant (engines). These indexes summed to create a fleet standardization index. Note that despite the authors' effort to measure commonality accurately, a realistic – and complete – set of components, including crew interchangeability, goes beyond the aircraft cells and engines. To calculate actual fleet commonality levels, one needs to consider thousands of distinct aspects of flight equipment and operations. Since this measurement is quite complicated, researchers have utilized indices of fleet standardization instead of a direct metric of fleet commonality. For example, Zou et al. (2015) use Herfindahl-Hirschman concentration indices (HHI) to create a three-level approach to fleet standardization, considering aircraft models, families and manufacturers. The main idea behind the study is that a standardized fleet is more likely to have interchangeable components and crew. Thus, one can use fleet standardization as a proxy for fleet commonality and its effects on the costs and operational efficiency of airlines.

2.2. Fleet management and airline business models

According to Clark (2007), fleet planning depends on several parameters. A perfectly adaptable and flexible fleet that satisfies all the interests of an airline is nearly impossible. Nevertheless, the aircraft choices regarding fleet planning are based on many operational, financial and strategic aspects that, when combined, may allow the airline to minimize its costs and maximize its operational profit (Holloway, 2008). Among fleet planning strategies, a key tool is the airline's fleet standardization (AFS) setup. AFS is a characteristic commonly associated with low-cost carriers (LCC). The reason for this association stems from the perception that a more standardized fleet contributes to lower costs in training and maintenance, and a higher capacity for schedule recovery – Gillen (2006), Kilpi (2007), Berrittella et al. (2009), Brüggen and Klose (2010), and Daft and Albers (2015). However, fleet standardization is not always a characteristic of LCCs. Whereas low fleet diversification is a notable characteristic of LCC Ryanair's fleet (1 aircraft model, 1 aircraft family, and 1 aircraft manufacturer) and of LCC Southwest's fleet (3 models, 1 family, and 1 manufacturer), other LCCs possess a higher fleet variety; for example, Jetstar's fleet (4 models; 3 families; 3 manufacturers) and JetBlue's fleet (3 models; 2 families; 2 manufacturers). The four airlines are all considered LCCs; yet have different standardization strategies. Similarly, it is possible to observe multiple fleet standardization positionings in the segment of full service carriers (FSCs), such as American Airlines (23 models; 13 families; 6 manufacturers), Lufthansa (13 models; 8 families; 4 manufacturers), Cathay Pacific (3 models; 3 families; 2 manufacturers) and Air Tahiti Nui (1 model; 1 family; 1 manufacturers).[6]

Kilpi (2007) and Brüggen and Klose (2010) suggest that fleet standardization is commonly high among low-cost carriers. Barros and Peypoch (2009) assess the performance of 29 European airlines and note that low-cost companies have higher operational efficiency than other airlines. Merkert and Hensher (2011) obtain a different result. Observing 58 airlines worldwide, they suggest that the low-cost business model setting apparently has no significant influence on the efficiency of airlines.

2.3. Consequences of fleet standardization

Regardless of the business model, Kilpi (2007) emphasizes that fleet standardization has generally decreased throughout the years, which could indicate airlines' interest in fleet diversification. Seristö and Vepsäläinen (1997) analyze the fleet composition of 42 airlines and find a negative correlation between fleet standardization and flight and maintenance costs. However, due to a low coefficient for the maintenance variable, the authors suggest that the real standardization cost savings is from flight costs. Zuidberg (2014) estimates a negative correlation between operational costs and fleet standardization. However, his results are statistically insignificant and the author concludes that there is little evidence that fleet standardization may affect operational costs.

Zou et al. (2015) assess ten years of data from 28 US airlines and suggest that standardization of aircraft model and/or family reduces airline unit costs. The authors also investigate the impact of fleet standardization on profit margins and find a positive correlation with aircraft family standardization. The authors conclude that airlines may use aircraft variability to adapt to demand variations and respond to rivals' actions. Therefore, a fully standardized fleet might lack the necessary flexibility for an airline to deal with competitive pressure, which in turn may reduce the airline' revenue generation capabilities. Similarly, West and Bradley (2008) suggest that a more diversified fleet is useful when an airline considers operating in different markets. However, despite the authors' hypothesis, their results indicate higher profit when fleet standardization is higher. West and Bradley (2008) find evidence that the cost of keeping many aircraft models may overweigh the benefits from the ability to better match available aircraft type to market demand through fleet diversity. They conclude, with Kilpi (2007), that fleet standardization has a positive correlation with airline profit margin. Consistent with this finding, Brüggen and Klose (2010) and Merkert and Hensher (2011) find evidence of positive associations between fleet standardization and operational efficiency.

As a summary of the literature provided in 2.1, 2.2 and 2.3, we may point to the following aspects. First, with respect to the concepts of fleet standardization and fleet commonality, the literature distinguishes the two concepts (Brüggen and Klose, 2010) and provides different metrics to inspect its effects on airline performance (Borges Pan and Espírito Santo, 2004; Zou et al., 2015). Some papers investigate the airline's business models at the same time as investigate AFS, but still with few analytical evidence of correlation between both aspects (Kilpi, 2007; Brüggen and Klose, 2010). With respect to operating performance, the few papers in the literature provide some evidence - but still without a clear consensus - on the benefits of AFS in lowering operating costs and enhancing profits of airlines (Seristö and Vepsäläinen, 1997; Kilpi, 2007; West and Bradley, 2008; Brüggen and Klose, 2010; Merkert and Hensher, 2011; Zuidberg, 2014; Zou et al., 2015). However, further investigation into the subject is certainly needed, mainly in topics not addressed before, such as the circumstances that motivates airlines to either increase, maintain or reduce the degree of AFS. Aiming that, the present paper treats AFS as a dependent variable and estimates the effect of business model and merger events on fleet adjustments of airlines over time.

3. Research design

3.1. Application

We consider the Brazilian airline industry in the 2002–2017 period. Scheduled domestic passenger air transportation in Brazil has developed significantly over the last decades. Additionally, the 2010s marked a notable upsurge in competition among airlines in the country. In fact, when comparing the 2010–2018 and 2002–2009 periods, concomitant with a drop in the city-pair market concentration levels measured by the Herfindahl-Hirschman index, which fell by 13.1%, price competitiveness intensified sharply, with the average real yield on domestic markets

[6] The fleet of each airline was verified at its own website on Jan 18th, 2018, and the LCC-FSC airline classification was based on the ICAO's document "List of Low-Cost-Carriers (LCCs) based on ICAO definition," available at *icao.int*.

falling from BRL 0.90 to BRL 0.385, or over 50% over the same period.[7] These factors evidence the increased competitive pressure exerted on airlines over the 2010s compared to the preceding decade.

Aircraft in the Brazil airline industry increased from 361 in 2000 to 447 in 2010, a fleet expansion of 24% equivalent to nine additional aircraft per year. In the first half of the 2010s, the industry underwent an accelerated growth cycle, reaching 571 aircraft in 2015, an increase of 26% in five years, with the addition of 23 aircraft per year. However, with the recent recession and economic slowdown in the country, airlines have experienced intense capacity reduction, cutting the fleet to 489 aircraft in 2017, which can be translated to 72 fewer aircraft from two years earlier.[8]

The composition of the aircraft fleet in the Brazilian domestic market has changed significantly over the decades due to new technologies introduced by manufacturers and to the larger operational scale allowed by quick market growth. In 2000, the two main aircraft utilized in the market were smaller narrowbody jets (up to 136 seats), with the Fokker-100 being the most-used aircraft (89 units), followed by the Boeing 737–300 (46 units). In contrast, in 2010 the two most-used aircraft were the Airbus A320 and the Boeing B737-800, with 87 and 72 units, respectively. The widespread use of these most advanced, higher-seat-capacity aircraft in the market represents a strong manifestation of the “upgauging” phenomenon, characterized by carriers replacing smaller planes with larger ones to meet demand growth.

The air transport market in Brazil had a peculiar characteristic over the analyzed period regarding the manufacturer, Embraer. Although it was a major aircraft supplier from the 1970s to the mid-1990s, aircraft from this manufacturer virtually disappeared from the country’s domestic markets in the 2000s. However, there was a significant demand for aircraft smaller than the traditional existing commercial jets to serve regional aviation and hub-bypass segments of the industry. This gap only began to be filled by the end of this decade, with the expansion of Trip Airlines and the entry into many of these routes by Azul Airlines, ultimately leading to a merger between the two companies. These factors contributed to the rapid expansion of Embraer aircraft in the Brazilian market between the late 2000s and mid-2010s.

The Brazilian air transport market has traditionally comprised three or four airlines, of which in general two or three are major carriers. The market structure in the industry clearly depends on the status of the economy’s overall condition, which is subject to uneven growth. During the sample period, we have four companies: Tam Airlines, Gol Airlines, Azul Airlines and Avianca Brasil Airlines.[9] Tam (now Latam Airlines) was formed in the 1970s, becoming the country’s leading full-service carrier in the mid-2000s. Gol Airlines (founded in 2001) and Azul Airlines (founded in 2008) are considered the country’s low-cost airlines.[10]

Avianca Brasil originated from a remarkable change in business models over the sample period. Its origins were from Oceanair, a small regional airline founded in 2003. In April 2010, after a market repositioning, the carrier was rebranded as Avianca Brasil. The new airline quickly promoted the replacement of its fleet of Embraer E−120 and Fokker F-100 – used to service regional aviation and some denser routes – by Airbus A320 aircraft in the early 2010s. This provided a significant change in the company’s strategy, as Avianca Brasil began competing with Azul in many domestic markets. Thus, Avianca Brasil shifted from focusing on a business model based on regional aviation to become the fourth largest Brazilian airline serving major markets. In 2019, however, the company became bankrupt and went out of business.

As Table 1 shows, Avianca and Gol had the highest airline fleet standardization indices (AFS). On the other hand, the major full-service carrier, Latam, had the lowest level of fleet standardization. The intermediate AFS level of Azul Airlines suggests that this carrier may pursue a hybrid business model. In fact, with many smaller narrowbody jets (Embraer E−190 and E−195) and a set of turboprops (ATR-72), Azul is linked to the regional business model, in addition to following a low-cost airline strategy [11].

An important characteristic of the sample period concerns a set of industry consolidation events arising over a five-year period – between 2007 and 2012 – in the form of mergers and acquisitions involving most major and medium-sized carriers in the country. In April 2007, the first of these moves occurred with the Gol-Varig merger (Event I), as the ultimate outcome of Varig’s turbulent bankruptcy process. The legacy carrier, Varig Airlines, was for decades the largest airline in Brazil, and a recognized brand both domestically and internationally. The carrier’s bankruptcy process was the first to be carried out under the country’s new Bankruptcy Law, passed in 2005, and as a result was involved in clear learn-by-doing dynamics, both by the company’s management and by the authorities in charge. Varig was the holder of key slots at one of the most important airports in the country – the São Paulo/Congonhas Airport (CGH). Its demise allowed Gol to become a dominant carrier at that airport. In December 2009, Tam Airlines, aiming to obtain additional slots at that airport, acquired the small regional company Pantanal Airlines (Event II). In July 2011, Gol Airlines acquired a medium-sized low-cost rival, Webjet Airlines (Event III). Lastly, in 2012, two mergers were announced: in May, the acquisition of Trip Airlines – then the second largest regional airline on the continent – by Azul Airlines (Event IV), and in June, the formation of Latam Airlines, arising from the association of the two largest companies in Brazil (Tam) and Chile (Lan Chile) and thus creating the largest airline in Latin America (Event V).[12] These five mergers comprise the event studies for the present work. We suspect that these mergers had a significant impact on the involved airlines’ fleet planning strategies, and in particular on their fleet standardization and diversification strategies throughout the Post-Merger Integration Period (PMI). Our empirical model aims to examine these issues and to econometrically test the effects of these events.

3.2. Data

Our dataset comprises a panel of the four key carriers in Brazil (Tam, Gol, Azul and Avianca), with monthly observations from January 2000 to December 2017. In 2017, these carriers accounted for 96% of the country’s total domestic flights. The initial dataset comprised 705 observations. To account for the fact that decision-making regarding the strategic fleet planning of carriers is typically performed over many periods in advance – considering the process of placing orders for new aircraft or used aircraft leases and the timing of the deliveries of the aircraft – we consider a lag of 24 months in the regressors of our empirical specification. We also verify the sensitivity of this lag choice in a robustness check. With lagged variables, our final model comprises 16 years over 192 periods (months).

Most data are publicly available from the website of the National Civil Aviation Agency (ANAC). More specifically, we utilize the Air

[7] Source: National Agency of Civil Aviation, Air Transport Statistical Database, Domestic Yield Report, with own calculations. BRL is Brazil’s currency (the *real*). The decrease in yields of the period is notable if we consider that fuel and capital expenses are tied to US dollars. The mean nominal exchange rate BRL/USD actually increased from 2.41 (2002–2009) to 2.62 (2010–2018), i. e. depreciation of 8.7% in the domestic currency - Source: Central Bank of Brazil, with own calculations -, which constituted an important cost pressure on the domestic carriers.

[8] Source: National Agency of Civil Aviation and Department of Civil Aviation - Air Transport Yearbooks (2000–2017).

[9] Not to be confused with Avianca Colombia.

[10] As a result of the strong cost competitiveness of full-service carrier Tam, and its price competitiveness, there is debate as to whether Gol and Azul still belong to the low-cost segment; for a discussion of this issue, see Oliveira et al. (2019).

[11] Panorama ABEAR 2016, available at www.abear.com.br. Fleet count of December 31, 2016.

[12] It is important to note that at the time of the merger, Lan Chile did not operate in the Brazilian domestic market.

Table 1
Presents the fleet composition of the major Brazilian carriers in 2016.

Airline	Fleet composition (2016)					AFS
	Aircraft Count	Aircraft Model	Aircraft Family	Aircraft Manufacturer	Fleet Size	
Avianca (AVI)	10	A318	A320	Airbus	47	*0.489*
	4	A319	A320	Airbus		
	31	A320	A320	Airbus		
	2	A330-200	A330	Airbus		
Azul (AZU)	5	A320	A320	Airbus	123	*0.381*
	5	A330-200	A330	Airbus		
	39	ATR72	ATR	ATR		
	10	E190	E190/95	Embraer		
	64	E195	E190/95	Embraer		
Gol (GOL)	28	B737-700	B737	Boeing	120	*0.642*
	92	B737-800	B737	Boeing		
Latam (TAM)	21	A319	A320	Airbus	147	*0.276*
	65	A320	A320	Airbus		
	31	A321	A320	Airbus		
	6	A350	A340/350	Airbus		
	14	B767-300	B767	Boeing		
	10	B777-300	B777	Boeing		

Source: Brazilian Airlines Association 2016 Outlook, with own calculations. AFS is calculated by extractingthe Herfindahl-Hirschman Index (HHI) of aircraft models, as in Zou et al. (2015).

Transportation Market Statistics Database, the Active Scheduled Flight Report (VRA), the Civil Aviation Integrated System (SINTAC), and the Brazilian Aeronautical Registry (RAB) datasets. The main sources for fleet standardization airlines are RAB and SINTAC. The RAB database provides detailed information of active and inactive aircraft in the country, while the SINTAC report provides detailed information on daily flights by aircraft registration (tail) number – allowing a direct association between the characteristics of each aircraft model and each observed flight. The active fleet of each airline is calculated on a monthly basis to determine the fleet standardization index by airline for each time period.

Variables related to the number of revenue passengers flown are obtained from the ANAC Air Transport Market Statistics Database, a monthly report containing information on all domestic scheduled routes in Brazil. With these data, it is possible to construct route level variables, such as market concentration, as well as the mean and standard deviation of traffic density, on domestic routes. The socioeconomic data were obtained from the websites of the Brazilian Institute of Geography and Statistics (IBGE), the Central Bank of Brazil (BACEN) and the Institute for Applied Economic Research (IPEA). All monetary variables were adjusted by a deflator based on the Extended National Consumer Price Index (IPCA) of IBGE. Information on the time and routes of the airline codeshare agreements came from the Ministry of Finance. The dates regarding the companies' market events (mergers, changes in business models, bankruptcies) were collected from digital media press websites. Jet fuel prices were obtained from the National Agency for Petroleum, Natural Gas and Biofuels.

3.3. Econometric model

Equation (1) presents our empirical model to investigate key drivers of the airline fleet standardization (AFS) of carriers in Brazil:

$$\begin{aligned} AFS_{it} &= \beta_1\, AFS_{it\text{-}h} + \beta_2\, FUEL_{it\text{-}h} + \beta_3\, RHHI_{it\text{-}h} + \beta_4\, GDPACC_{t\text{-}h} \\ &+ \beta_5\, PAXSD_{it\text{-}h} + \beta_6\, BANKRUPT_t + \beta_7\, BMCHNG_{it} \\ &+ \beta_8\, CSHARE_{it} + \beta_9\, T_t + \beta_{10}\, T_t \times SLOWDOWN_t \\ &+ \beta_{11}\, MERGER_{it} + \beta_{12}\, MERGER_{it} \times PMIT_{it} + \gamma_i + u_{it}, \end{aligned} \quad (1)$$

where i denotes the airline ($i = 1, ..., 4$ airlines), t denotes the time period ($t = 1, ..., 192$ months) and h denotes a time lag for strategic decision making ($h = 24$ months in our baseline model). The components of equation (1) are the following:

- AFS_{it} is a proxy for the degree of airline fleet standardization. It is the Herfindahl-Hirschman Index (HHI) of active aircraft models of airline i at year-month t. It is equal to the summation of the squared participation of each aircraft model in the airline's fleet. As in Zou et al. (2015), the participation of an aircraft model is defined as the number of aircraft belonging to that model over the total number of aircraft in the fleet. The inverse of AFS is equal to the number of "equal-share" aircraft models utilized by the carrier, being a proxy for fleet diversification.
- $AFS_{it\text{-}h}$ is equal to AFS_{it} lagged by h periods, included in the specification to account for the dynamic adjustments in fleet standardization accomplished by carrier i over time. We set $h = 24$ in our main models as a reasonable strategic planning horizon for airlines, but experiment with different lags in the robustness checks. The estimated coefficient of this lagged component of AFS is expected to be relatively low because, due to the competitiveness of the airline market, fleet standardization or diversification movements by carriers tend to occur in the form of adjustments over relatively few years. For example, in the early 2000s when Tam Airlines replaced its fleet of Fokker 100s – its main aircraft model at that time – with Airbus A320s its main aircraft model – its AFS rates fell at first but quickly increased when the new aircraft became widely used in its fleet. Unless there are relevant barriers to the management's fleet strategic flexibility, such as scope clauses, unions, queues on delivery by manufacturers, etc., the persistence of the AFS series can be expected to be relatively low, revealing transitory fleet adjustments (low persistence).
- $FUEL_{it\text{-}h}$ is the mean price of jet fuel in the markets served by carrier i at time $t\text{-}h$. This metric aims at capturing the effects of cost pressures on fleet standardization strategies.
- $RHHI_{it\text{-}h}$ is the mean route concentration in the markets served by carrier i at time $t\text{-}h$. It is calculated as the Herfindahl-Hirschman Index (HHI) of passengers in the city-pair market. This variable aims to control for the effects of competitive pressures on airline fleet standardization.
- $GDPACC_{it\text{-}h}$ is the mean acceleration in the real gross domestic product of the origin and destination cities of the city-pair markets served by carrier i at planning time $t\text{-}h$. GDP is measured as the geometric mean of origin and destination cities. It is equal to the twelve-month compound growth rate of GDP at time $t\text{-}h$ over the same metric calculated for time $t\text{-}h\text{-}12$. This variable is intended to capture the effects of growth in the economy on the expectations of fleet planning managers.

- $PAXSD_{it-h}$ is the standard deviation of city-pair density; that is, the number of daily revenue passengers carried by airline *i* across its routes at time *t-h.* This variable is a proxy for the heterogeneity of routes in the network of carrier *i* and therefore is a source of pressure for fleet diversification.
- $BANKRUPT_t$ is a dummy to control for the presence of a bankrupt carrier in the domestic airline industry at time *t.* It accounts for the bankruptcy events of Transbrasil (December 2001), Vasp (January 2005), Varig (June 2006) and BRA Airlines (November 2007). It is assigned a 1 for all sample carriers from the ending period of the bankruptcy up to one year after the respective event. It is designed to control for the pressures of quick capacity expansion to absorb the market left by the bankrupt carrier.
- $BMCHNG_{it}$ is a dummy to control for the period after the announcement of the business model change by Avianca Brasil (April 2010). It is equal to 1 only for that carrier up to four years after the public announcement.
- $CSHARE_{it}$ is a dummy to control for the period of the codeshare agreement between Tam and Varig Airlines (March 2003 to April 2005). It is equal to 1 for Tam during the codeshare operations period.
- T_t is a trend variable, i.e., a sequence equal to 1, 2, 3, ..., TP, where TP the total number of periods in the sample. With this variable, we aim to determine an overall tendency in higher fleet standardization (and lower fleet diversification) by the carriers under analysis.
- $SLOWDOWN_t$ is a dummy variable to account for the period of the Brazilian technical recession (2014q2 to 2016q4). In principle, during a recession the number of profitable air travel markets decreases and therefore the need for a diversified fleet decreases as a consequence. In addition, carriers may prefer higher fleet standardization to become more cost-efficient when demand is low.
- $MERGER_{it}$ is a dummy variable to account for the five merger events observed in the market in the sample period: Gol-Varig (Event I, from April 2007), Tam-Pantanal (Event II, from December 2012), Gol-Webjet (Event III, from July 2011), Azul-Trip (Event IV, from May 2012) and Latam (Event V, from June 2012). This variable is set equal to 1 from the public announcement of the merger for the period of four years. The only exception relates to Event II, in which the variable is set equal to 1 until the month prior to the start of Event V. As most merging parties in our events had different fleets on the occasion of the announcement of the merger, we expect a negative sign for the coefficient of this variable.
- $PMIT_{it}$ is a merger event-specific time trend to account for the dynamics of fleet standardization during the postmerger integration period (PMI). This variable is set with a sequence 1, 2, 3, ..., from the announcement of the respective merger and is equal to 0 before the event. In the event of a trend reversing the negative impact of the merger on the fleet standardization of the merged firm, we expect the sign of the estimated coefficient of this variable to be positive.
- γ_i is a carrier-specific fixed effect.
- u_{it} is the error term.
- $\beta_1, \ldots, \beta_{12}$ are unknown parameters.

Henceforth, we omit indexes *i* and *t.* Table 2 presents the descriptive statistics of the variables of our empirical model.[13]

3.4. Estimation strategy

We consider a fractional heteroskedastic probit regression to estimate the main drivers of airline fleet standardization in Brazil. By definition, a fractional response regression is a model with a continuous dependent variable that is bounded between 0 and 1, such as proportions and fractions. The classic framework was proposed by Papke and Wooldridge (1996), and the underlying empirical model may be either probit or logit for the conditional mean. The estimation method is the quasi-maximum likelihood estimation (QMLE). We utilize the probit specification but also consider the logit model as a robustness check. The setup of the heteroskedastic probit requires the indication of variables to control for the variance of the error term. In our context, we utilize the mean route density of each carrier's network over time to model that variance.

An extension of the fractional response regression to a fixed-effects context is provided by Papke and Wooldridge (2008). Here, as in Hausman and Leonard (1997) and Wagner (2003), we utilize airline dummies to control for firm-specific intercepts and therefore to model unobserved heterogeneity across carriers. Papke and Wooldridge (2008) observe that including cross-sectional dummies may be a procedure that suffers from an incidental parameters problem when the number of time periods is small but the number of cross-sections is large. The authors note that the incidental parameter problem does not emerge when the dataset contains many observations by cross section. Therefore, fractional response models with fixed effects controls are consistent with panel data with a small cross-sectional dimension and relatively numerous time periods, as in our case.

Few studies have employed fractional response regressions in the air transportation context; Prince and Simon (2009), Cao et al. (2017) and Alderighi and Gaggero (2018) are among these papers. This research aims to determine the drivers of service quality in the industry, focusing on estimating the proportion of flights cancelled or flights arriving late. As far as we are aware, our proposed framework is the first to employ fractional response models to estimate the determinants of airline decision-making regarding fleet planning decisions.

4. Estimation results

Table 3presents the estimation results of our empirical models of AFS for Brazilian airlines. Column (3) presents our preferred specification, which includes the merger dummy variable (MERGER) and the interacted variable representing the post-merger integration time trend (MERGER × PMIT). We present columns (1) and (2) to inspect the sensitivity of the model results when these variables are omitted. One can see that the models produce results that are relatively robust across columns. One variable that is sensitive, however, is the market concentration index (RHHI), which becomes insignificant from column (2), after the inclusion of MERGER. This change in significance is revealing and suggests that merger episodes are generally associated with the largest increases in market concentration. Once the mergers are controlled in the model, the effect of market concentration on fleet standardization completely dissipates. We therefore find evidence that market concentration in the period apparently has an effect on airline fleet standardization–diversification decisions through the effect of the observed merger events.

We can see that the estimation results in Table 3 are consistent with prior expectations of the signs and statistical significance of most coefficients. For example, the price of fuel – the FUEL variable – has an estimated effect of increasing airline fleet standardization, meaning that in times of cost pressures airlines aim to reduce their aircraft diversification to target higher cost competitiveness. On the other hand, the variability of markets served – PAXSD – has a reducing effect on fleet standardization, an expected result given the need for a more diversified fleet to service a portfolio of markets. The lagged fleet standardization variable (AFSI) indicates that carriers with higher fleet standardization levels tend to be those that seek to strengthen their fleet planning strategies over time. In this sense, it is not possible to infer any attempt at business model changes by the airlines, at least with respect to the fleet standardization dimension. It is important to note, however, that this result may simply indicate that carriers are sequentially receiving from the manufacturer a set of aircraft that is consistent with their current fleets. With respect to the nonmerger related market events – the

[13] Table 4 shows the Pearson correlation between variables.

Table 2
Descriptive statistics of variables.

Variable name	Type	Nr obs	Mean	Std Dev	Min	Max
AFS	index (0,1)	705	0.511	0.166	0.221	1
AFS (lagged)	index (0,1)	609	0.511	0.173	0.221	1
FUEL (lagged)	real monetary units	609	2.583	0.536	1.179	4.006
RHHI (lagged)	index (0,1)	609	0.601	0.112	0.314	0.896
GDPACC (lagged)	rate	669	−0.006	0.062	−0.142	0.186
PAXSD (lagged)	count	613	4468.882	2467.971	98.767	10037.038
BANKRUPT	dummy	705	0.148	0.355	0	1
BMCHNG	dummy	705	0.068	0.252	0	1
CSHARE	dummy	705	0.040	0.195	0	1
T	sequence (1,2, …)	705	123.501	57.660	1	216
SLOWDOWN	dummy	705	0.187	0.390	0	1
MERGER	dummy	705	0.315	0.465	0	1
PMIT	sequence (1,2, …)	705	7.332	13.253	0	48
AFSRIV (lagged)	index (0,1)	669	0.481	0.084	0.310	0.738
SHLCCRIV (lagged)	fraction	669	0.292	0.196	0	0.628
PAXACC (lagged)	rate	561	1.657	16.629	−52.628	387.805
IPO	dummy	705	0.081	0.273	0	1
PIT	sequence (1,2, …)	705	1.732	7.170	0	48

Note: continuous regressors lagged by 24 months (main models).

BANKRUPT, BMCHNG and CSHARE variables – it is possible to note that the bankruptcies, the episode of business model change and the code-share agreement observed in the sample period are associated with greater fleet diversification by carriers. Equally important, the acceleration in economic growth – the GDPACC variable – is not statistically significant, indicating that companies apparently do not change their strategic fleet planning based on short-term fluctuations in the economy.

To more thoroughly investigate the effects of the consolidation events, the MERGER dummy variable was divided to represent the five mergers observed in the period, namely, Gol-Varig (Event I), Gol-Webjet (Event II), Azul-Trip (Event III), Tam-Pantanal (Event IV) and Latam (Event V). Columns (5) and (6) of Table 3 present the results.[14] Column (5) displays the results of the specification containing general trend variables – i.e., T and T × SLOWDOWN. Column (6) contains the results incorporating firm-specific trends – i.e., T and T × SLOWDOWN interacted with airline dummies AZU, TAM, GOL and AVI. Interestingly, we can see in column (5) that the Azul-Trip merger has the highest estimated impact on AFS, suggesting that this consolidation may have produced the largest effect of fleet diversification among those merger events observed in the period. Column (5) also allows us to observe that merger events in general have an estimated decreasing effect on airline fleet standardization. The only exception is Event V, which may be interpreted in line with the fact that the constitution of the Latam group involved a company (Lan Chile) that did not operate in the Brazilian domestic market and therefore did not involve immediate fleet transfers between domestic merging carriers. Furthermore, and as expected, all other mergers showed an estimated positive effect of the interacted variable MERGER × PMIT, which is suggestive of a long-term evolution in which the initial decreasing effects of mergers are eventually dissipated. Regarding the estimation results of the specific trends of the airlines, it can be noted in column (6) that, except for TAM, all other carriers have an estimated trend suggesting a path toward higher fleet standardization (and lower diversification) in the sample period. These results suggest that the competition prevailing in the industry since the early 2010s has led carriers to form a stronger preference for sustaining cost competitiveness, rather than to seek new opportunities in the market. Moreover, the economic slowdown period may have intensified such a preference in some cases.

To better visualize the results in column (6), we present the charts in Fig. 1. This figure contains the evolution of the predicted values of the AFS variable over time for the mergers of Events I, II, III and IV. These were the events with statistically significant effects. For our events study, we constructed a time window which starts one quarter before the merger event and continues until several quarters after it.[15] The charts display both the predicted AFS values computing the estimated effects of the merger – the "Predicted (With Merger)" series in Fig. 1 – and the predicted AFS values simulating the scenario in which the merger effects were not included – the "Predicted (No Merger)" series. In these computations, the effects of both the MERGER and the MERGER × PMIT variables were utilized. We observe that in the four mergers there is an initial and immediate decline in the fleet standardization of the companies in quarter 0 – an expected consequence of the incorporation of the acquired company's fleet into the acquiring company. However, the estimation results suggest a medium-term tendency to dissipate that effect. In fact, in all charts it is possible to see a clear evolution pattern of convergence between the series of predicted values with and without merger. This convergence, however, may take more, or less, time depending on some of the main characteristics of the merger. We can see that the convergence timing of the two series is the longest in the case of Event I (Gol-Varig merger), which is estimated to be approximately 25–26 quarters. This result can be interpreted as a consequence of the bankruptcy process suffered by Varig in the year prior to the merger, as discussed earlier. This point highlights the greater complexity of the Gol-Varig merger operation, which may have materialized in Gol's apparent gradual fleet planning decision-making in the post-merger integration period. In the other cases shown in Fig. 1 – i.e., Events II, III and IV – a window of up to 15 quarters is observed so that there is full convergence between the "With Merger" and "No Merger" simulated series. This clearly indicates that, during these merger episodes, integrated corporate management was much more efficient and agile in promoting a return to the previously observed fleet standardization-diversification state.

In sum, the estimation results in Table 3 and Fig. 1 are evidence that the four merger events that involved two domestic carriers induced a short-term effect on the fleet-planning strategies of the acquiring airlines

[14] To inspect the issue of multicollinearity, we report mean variance inflation factor (VIF) statistics of the variables of estimated model. We also present a correlation table of the main variables in the Appendix. It is possible to see that the specifications of Columns (1)–(5) do not suffer from multicollinearity, as the mean VIF statistic is relatively low. In contrast, specifications in Columns (6) and (7), present mean VIF statistics much higher and should be analyzed with particular attention to possible false negative results.

[15] Note that for the development of the charts in Fig. 1, the MERGER × PMIT variables are not set to zero after the period of four years (see the description of MERGER). This procedure allowed us to simulate the effects of the merger over an extended period.

Table 3
Estimation results: airline fleet standardization (AFS).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	AFS	AFS	AFS	AFS	AFS	AFS	AFS
AFS (lagged)	0.3157^{a}	0.3133^{a}	0.3220^{a}	0.3839^{a}	0.3281^{a}	0.3704^{a}	0.3521^{a}
FUEL (lagged)	0.0381^{b}	0.0487^{a}	0.0542^{a}	0.0806^{a}	0.0625^{a}	0.0852^{a}	0.0947^{a}
RHHI (lagged)	-0.2312^{a}	−0.1062	−0.1038	0.0974	−0.1079	-0.1868^{b}	−0.1283
GDPACC (lagged)	−0.1208	−0.1193	−0.1300	−0.0909	-0.1558^{c}	-0.1896^{b}	-0.1727^{b}
PAXSD (lagged)	-0.5165^{a}	-0.4471^{a}	-0.3726^{a}	-0.1891^{a}	-0.3789^{a}	-0.3400^{a}	-0.2950^{a}
BANKRUPT	-0.0497^{a}	-0.0670^{b}	-0.0790^{a}	-0.1495^{a}	-0.0894^{a}	-0.1002^{a}	-0.0938^{a}
BMCHNG	-0.2899^{a}	-0.2835^{a}	-0.2956^{a}	-0.3391^{a}	-0.3082^{a}	-0.4476^{a}	-0.4351^{a}
CSHARE	-0.0660^{a}	-0.0703^{a}	-0.0767^{a}	-0.1115^{a}	-0.0842^{a}	-0.1153^{a}	-0.1115^{a}
T	0.0026^{a}	0.0025^{a}	0.0022^{a}	0.0009^{a}	0.0022^{a}		
T × SLOWDOWN	0.0001	0.0000	-0.0003^{c}	-0.0005^{a}	-0.0005^{a}		
MERGER		-0.0730^{a}	-0.1631^{a}	-0.1510^{a}			
MERGER × PMIT			0.0040^{a}	0.0031^{a}			
Event I: Gol-Varig Merger							
$MERGER_1$					-0.1360^{a}	-0.1259^{a}	-0.1422^{a}
$MERGER_1 \times PMIT_1$					0.0017^{b}	0.0016^{b}	0.0005
Event II: Gol-Webjet Merger							
$MERGER_2$					-0.1529^{a}	-0.1029^{a}	-0.1474^{a}
$MERGER_2 \times PMIT_2$					0.0081^{a}	0.0032^{a}	0.0039^{a}
Event III: Azul-Trip Merger							
$MERGER_3$					-0.2732^{a}	-0.2344^{a}	-0.2410^{a}
$MERGER_3 \times PMIT_3$					0.0087^{a}	0.0049^{a}	0.0049^{a}
Event IV: Tam-Pantanal Merger							
$MERGER_4$					-0.1734^{a}	-0.1614^{a}	-0.1618^{a}
$MERGER_4 \times PMIT_4$					0.0030	0.0062^{a}	0.0069^{a}
Event V: Latam Merger							
$MERGER_5$					−0.0311	0.0248	0.0429
$MERGER_5 \times PMIT_5$					-0.0060^{a}	−0.0009	−0.0014
T × AZU						0.0013^{b}	0.0009
T × TAM						0.0006	0.0003
T × GOL						0.0023^{a}	0.0019^{a}
T × AVI						0.0036^{a}	0.0036^{a}
T × SLOWDOWN × AZU						0.0002^{b}	0.0002
T × SLOWDOWN × TAM						-0.0010^{b}	-0.0009^{b}
T × SLOWDOWN × GOL						0.0000	−0.0001
T × SLOWDOWN × AVI						-0.0022^{a}	-0.0022^{a}
IPO × GOL							-0.1016^{a}
IPO × AZU							0.0188
IPO × PIT × GOL							0.0011^{c}
IPO × PIT × AZU							-0.0020^{b}
Fractional resp model	probit	probit	probit	logit	probit	probit	probit
Airline dummies	yes	yes	yes	yes	yes	yes	yes
Adj R^2 Statistic	0.4603	0.4951	0.5145	0. 5145	0.5631	0.6325	0.6412
RMSE Statistic	0.1148	0.1110	0.1089	0.1089	0.1033	0.0947	0.0936
CV RMSE Statistic	0.1155	0.1118	0.1110	0.1105	0.1035	0.0871	0.0842
Wald Statistic	181.58	204.24	216.79	936.89	279.39	397.12	506.66
VIF Statistic	4.68	4.63	4.90	4.90	5.73	36.16	44.19
AIC Statistic	842	843	844	844	857	864	871
BIC Statistic	908	914	919	915	968	1,001	1,026
Nr Observations	609	609	609	609	609	609	609

Notes: results (marginal effects) produced by the fractional response model of Papke and Wooldridge (1996); fractional heteroskedasticity probit estimation implemented utilizing the number of monthly revenue passengers by carrier to account for the variance of error. Airline dummies estimates omitted; adjusted R2 and RMSE statistics extracted from an equivalent least-squares dummy-variables estimator (LSDV); CV RMSE is the RMSE calculated from a 5-fold cross-validation procedure; p-value representation, a means $p < 0.01$,b means $p < 0.05$, c means $p < 0.10$.

that reduced their fleet standardization levels and then boosted their fleet diversification. Furthermore, there is evidence that the post-merger integration management efforts eventually led to a return to the original state of fleet standardization after several months' time. The speed with which the premerger state is reached may be proportional to the complexity of the operations of the acquired company, and the urgency in restoring the previous market positioning by the acquiring company following the merger.

5. Robustness checks

To verify the sensitivity of the main estimation results, we performed a set of robustness checks. First, we experimented with the application of the fractional logit model, a replacement for the fractional probit model. The results are displayed in Table 3, column (4). Second, we aimed to control for other important events in the period whose omission could provoke inconsistent estimation and bias. In particular, we control for the effects of the Gol and Azul stock market launch, which occurred respectively on June 24, 2004 and April 11, 2017. Both events were dual Initial Public Offerings (IPOs) – i.e., concomitantly on the São Paulo and New York stock exchanges – and were very successful raising considerable funds for the carriers: Gol raised US$ 281 million and Azul raised US$ 645 million.[16] The primary purpose of a carrier's IPO may be to allow for quick network expansion and intensified aircraft acquisition. In this sense, an IPO may represent a confounding effect with a merger

[16] Sources: "GOL Marks Anniversary of Debut on Stock Exchanges," available at *ir.voegol.com.br*, June 24, 2005; and "Azul, shareholders fetch $645 million in bigger-than-expected Brazil, U.S. IPO," available at *reuters.com*, April 10, 2017.

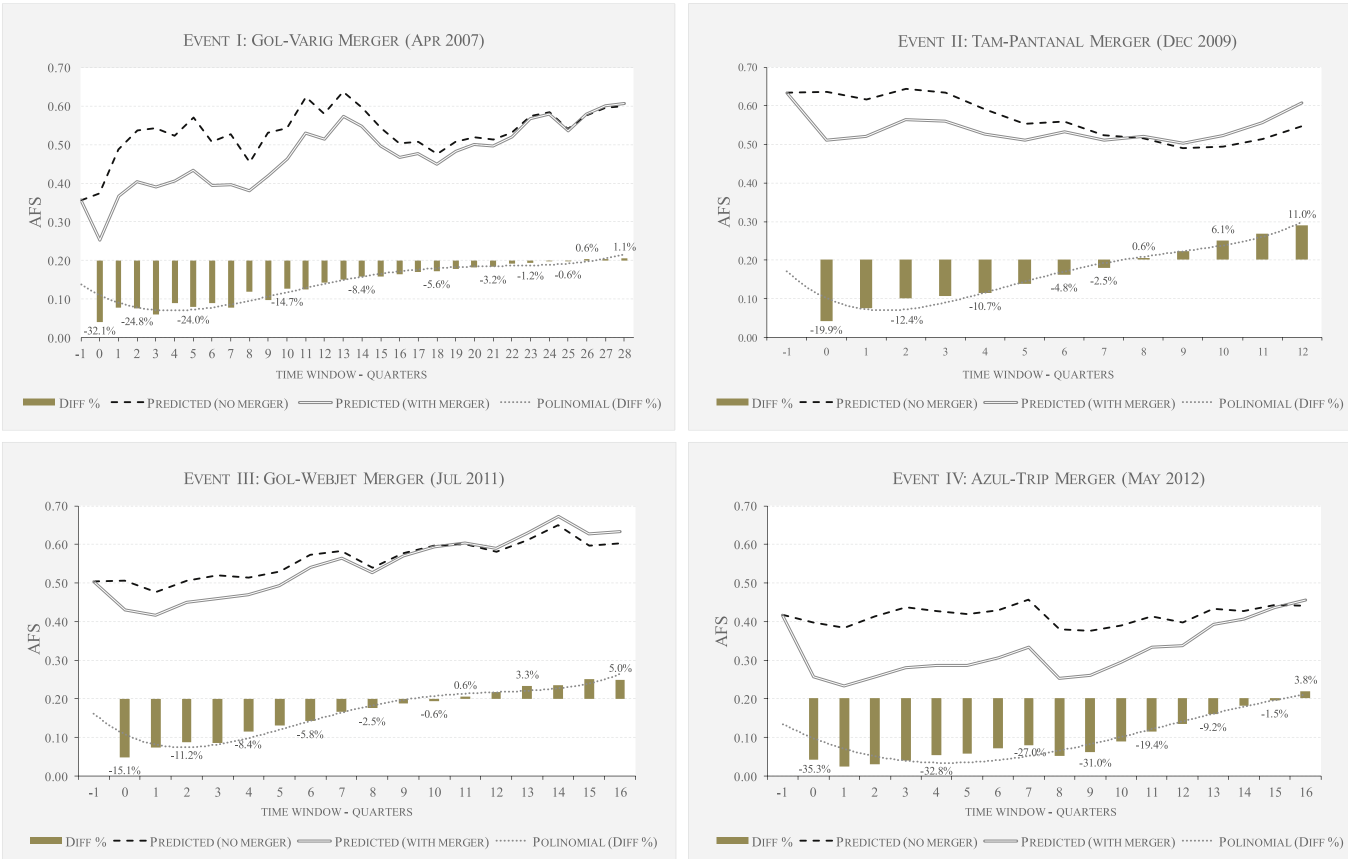

Fig. 1. Estimated dynamic impact of the statistically significant merger events.

event with respect to airline fleet diversification strategies. To examine the potential confounding of IPO financial effects with merger effects on airline fleet-planning strategies, we used the IPO dummy variable as well as its interaction with a post-IPO trend variable (IPO × PIT). Column (7) of Table 3 shows the results of the insertion of the variables related to the IPOs. Another experiment was to insert a proxy for the variation of route distance in an airline's operation network as an additional potential explanatory variable, labelled as "DISTSD (lagged)".[17] As a final robustness check, we developed an analysis of the effects of the configuration of alternative lag values for the model's lagged regressors, which was set equal to 24 in the specifications of Table 3. In these experiments, we employed lag values of 12, 15, 18, 21, 27 and 30 months. The results of alternative estimates can be found in Tables 5 and 6. In none of the proposed robustness checks did we observe significant changes in the main estimation results of Table 3.

6. Conclusion

This paper develops an econometric framework to investigate the key drivers of strategic management regarding airline fleet standardization (AFS) in the Brazilian airline industry. In particular, we observe the impacts of five merger events that shaped competition in the market in the late 2000s and early 2010s. Our results provide evidence that consolidation has statistically significant impacts on the strategic fleet standardization–diversification decision-making of most carriers. We estimate that mergers provoke short-term decreases in the degree of AFS, followed by a reversing trend reestablishing the previously observed levels after 8 to 26 quarters. We argue that the speed of adjustment in the post-merger integration period may be inversely related to the complexity of the merger event. Additionally, except for one major full-service carrier, all other airlines had an estimated trend that indicated a path toward higher fleet standardization over the sample period, which is suggestive of a preference for cost competitiveness-targeting over market opportunities-seeking in an industry marked by intensified rivalry.

We believe our results may contain important implications from the perspective of merger policy of airlines. As in the medium-term they apparently restore their AFS to the levels observed before the merger, the regulatory concerns of authorities that the excess costs of merger integration can hinder major airline consolidations could be attenuated.

Because fleet standardization is an important mantra of the low-cost carrier paradigm, investigating the determinants of the fleet standardization strategies of airlines provides a means to inspect the adaptation of the business models in the industry with respect to market competitiveness. Additionally, given the recent problems faced by Boeing relative to its 737 Max aircraft, exposure to manufacturer-related reputational risks has become a very relevant business issue for airlines when establishing their fleet standardization settings. Thus, our study provides insights into a better understanding of the strategic fleet-planning of carriers in the context of competition, greater recurrent consolidation and increased uncertainty.

[17] DISTSD is the standard deviation of domestic route distances of a given airline/time, weighted by the number of flight frequencies on the route. Source: ANAC, with own calculations. That variable is highly correlated with "PAXSD (lagged)", which intensifies the issue of multicollinearity in the estimations of the full models, in Columns (6) and (7). The Pearson correlation coefficient between "PAXSD (lagged)" and "DISTSD (lagged)" is equal to 0.7910. Note that in this specification we also had to control for an apparent distinct strategy of Avianca - a bankrupt carrier of the period – with interaction terms. See Table 6 for the full estimation results. We thank one of the anonymous reviewers for suggesting this experiment.

CRediT authorship contribution statement

Rodolfo R. Narcizo: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. **Alessandro V.M. Oliveira:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. **Martin E. Dresner:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing.

Declaration of competing interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Appendix

Table 4
Pearson correlations of variables.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1)	AFS	1												
(2)	AFS (lagged)	0.2217	1											
(3)	FUEL (lagged)	0.1717	−0.3319	1										
(4)	RHHI (lagged)	0.1032	−0.2557	0.2010	1									
(5)	GDPACC (lagged)	−0.0051	0.0292	0.0722	0.0479	1								
(6)	PAXSD (lagged)	−0.0761	−0.1374	0.0917	−0.4106	−0.0989	1							
(7)	BANKRUPT	−0.1777	−0.0087	−0.1002	0.2417	0.0140	−0.2734	1						
(8)	BMCHNG	−0.0916	0.4486	0.0140	−0.2017	−0.0104	−0.2624	−0.1186	1					
(9)	CSHARE	−0.2017	−0.0873	−0.2848	0.0472	0.0406	−0.1035	0.0235	−0.0642	1				
(10)	T	−0.0056	−0.2480	0.2973	−0.2703	−0.1860	0.5618	−0.5124	0.0727	−0.3557	1			
(11)	T x SLOWDOWN	−0.0656	−0.2815	0.3379	−0.1032	−0.0691	0.3455	−0.2130	−0.1536	−0.1153	0.5496	1		
(12)	MERGER	−0.1652	−0.1890	0.2585	0.0942	0.0310	0.4036	−0.2777	−0.2215	−0.1663	0.2580	0.1335	1	
(13)	MERGER x PMIT	−0.0737	−0.2272	0.3039	0.1393	−0.0031	0.3324	−0.2456	−0.1786	−0.1340	0.3089	0.3629	0.8062	1

Table 5
Estimation results: airline fleet standardization (AFS) - robustness check (lags).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	AFS	AFS	AFS	AFS	AFS	AFS	AFS
AFS (lagged)	0.5537[a]	0.4746[a]	0.4929[a]	0.4259[a]	0.3220[a]	0.1363[b]	−0.2080[a]
FUEL (lagged)	0.0185[c]	0.0025	−0.0065	0.0240	0.0542[a]	0.0572[a]	−0.0144[c]
RHHI (lagged)	−0.1918[b]	−0.1323[c]	−0.0638	−0.0554	−0.1038	−0.1353	−0.4740[a]
GDPACC (lagged)	−0.0186	−0.0721	−0.0792	−0.2059[b]	−0.1300	0.0355	−0.0603[c]
PAXSD (lagged)	−0.0000[a]	−0.0000[a]	−0.0000[a]	−0.0000[a]	−0.0000[a]	−0.0000[a]	−0.0000[a]
BANKRUPT	−0.0265	−0.0478[b]	−0.0568[a]	−0.0765[a]	−0.0790[a]	−0.0970[a]	−0.0046
BMCHNG	−0.2857[a]	−0.3115[a]	−0.3622[a]	−0.3353[a]	−0.2956[a]	−0.2306[a]	−0.0219
CSHARE	−0.0183	−0.0396[a]	−0.0372[b]	−0.0632[a]	−0.0767[a]	−0.0934[a]	−0.0809[a]
T	0.0023[a]	0.0024[a]	0.0028[a]	0.0023[a]	0.0022[a]	0.0019[a]	0.0011[b]
T × SLOWDOWN	−0.0003[a]	−0.0003[c]	−0.0000	−0.0002	−0.0003[c]	−0.0004[a]	0.0014[b]
MERGER	−0.1290[a]	−0.1197[a]	−0.1058	−0.1295[b]	−0.1631[a]	−0.1556[a]	−0.0132
MERGER × PMIT	0.0045[a]	0.0044[a]	0.0038[b]	0.0043[a]	0.0040[a]	0.0037[a]	0.0010
Nr lags	12	15	18	21	24	27	30
Fractional resp model	probit	probit	probit	probit	probit	probit	probit
Airline dummies	yes	yes	yes	yes	yes	yes	yes
Adj R^2 Statistic	0.7073	0.6442	0.5840	0. 5491	0.5145	0.4648	0.4428
RMSE Statistic	0.0837	0.0923	0.0999	0.1043	0.1089	0.1148	0.1177
Wald Statistic	271.04	244.85	185.48	188.82	216.79	194.26	133.66
Nr Observations	657	645	633	621	609	597	585

Notes: results (marginal effects) produced by the fractional response model of Papke and Wooldridge (1996). Fractional probit estimation is implemented considering heteroskedasticity, with the number of monthly revenue passengers by carrier accounting for the variance of residuals. Airline dummies estimates omitted; adjusted R^2 and RMSE statistics extracted from an equivalent least-squares dummy-variables estimator (LSDV); p-value representations, ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

Table 6
Estimation results: airline fleet standardization (AFS) – robustness checks (DISTSD).

AAAA	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	AFS	AFS	AFS	AFS	AFS	AFS	AFS
AFS (lagged)	0.1684[a]	0.1689[a]	0.1856[a]	0.1856[a]	0.2046[a]	0.2526[a]	0.2189[a]
FUEL (lagged)	0.0116	0.0167	0.0239[b]	0.0239[b]	0.0357[a]	0.0638[a]	0.0758[a]
RHHI (lagged)	−0.0261	0.0002	0.0092	0.0092	0.0185	−0.0236	0.0918
GDPACC (lagged)	−0.0624	−0.0685	−0.0780	−0.0780	−0.0948[c]	−0.1041[b]	−0.0858[c]
PAXSD (lagged)	−0.2080[a]	−0.1891[a]	−0.1247[c]	−0.1247[c]	−0.1091	−0.1047[b]	−0.0089
DISTSD (lagged)	−0.0614[a]	−0.0425[a]	−0.0343[a]	−0.0343[a]	−0.0102	−0.0009	0.0004
BANKRUPT	−0.0376[a]	−0.0452[a]	−0.0557[a]	−0.0557[a]	−0.0698[a]	−0.0927[a]	−0.0756[a]
BMCHNG	−0.2056[a]	−0.2043[a]	−0.2320[a]	−0.2320[a]	−0.2572[a]	−0.4308[a]	−0.4031[a]
CSHARE	−0.0626[a]	−0.0671[a]	−0.0747[a]	−0.0747[a]	−0.0840[a]	−0.1241[a]	−0.1126[a]
T	0.0027[a]	0.0024[a]	0.0020[a]	0.0020[a]	0.0014[a]		
T × SLOWDOWN	0.0001	0.0001	−0.0002	−0.0002	−0.0004[b]		
MERGER		−0.0449[a]	−0.1267[a]	−0.1267[a]			
MERGER × PMIT			0.0034[a]	0.0034[a]			
<u>Event I: Gol-Varig Merger</u>							
$MERGER_1$					−0.1456[a]	−0.1628[a]	−0.1637[a]
$MERGER_1 \times PMIT_1$					0.0025[a]	0.0027[a]	0.0003
<u>Event II: Gol-Webjet Merger</u>							
$MERGER_2$					−0.1904[a]	−0.1260[a]	−0.1998[a]
$MERGER_2 \times PMIT_2$					0.0081[a]	0.0039[a]	0.0052[a]
<u>Event III: Azul-Trip Merger</u>							
$MERGER_3$					−0.2549[a]	−0.2518[a]	−0.2634[a]
$MERGER_3 \times PMIT_3$					0.0073[a]	0.0050[a]	0.0050[a]
<u>Event IV: Tam-Pantanal Merger</u>							
$MERGER_4$					−0.1075[a]	−0.1185[a]	−0.1201[a]
$MERGER_4 \times PMIT_4$					0.0014	0.0048[a]	0.0055[a]
<u>Event V: Latam Merger</u>							
$MERGER_5$					0.0009	0.0330	0.0503[b]
$MERGER_5 \times PMIT_5$					−0.0060[a]	−0.0010	−0.0015[b]
T × AZU						0.0000	−0.0006
T × TAM						−0.0001	−0.0004
T × GOL						0.0011[a]	0.0003
T × AVI						0.0023[c]	0.0027[b]
T × SLOWDOWN × AZU						0.0001[c]	0.0000
T × SLOWDOWN × TAM						−0.0007[a]	−0.0006[a]
T × SLOWDOWN × GOL						−0.0000	−0.0002[b]
T × SLOWDOWN × AVI						−0.0020[a]	−0.0020[a]
IPO × GOL							−0.1436[a]
IPO × AZU							0.0059
IPO × PIT × GOL							0.0006
IPO × PIT × AZU							0.0003
PAXSD (lagged) × AVI	−1.6311[a]	−1.5990[a]	−1.5438[a]	−1.5438[a]	−1.4702[a]	−1.6279[a]	−1.7693[a]
DISTSD (lagged) × AVI	0.1798[a]	0.1664[a]	0.1712[a]	0.1712[a]	0.1645[a]	0.2076[a]	0.2116[a]
Fractional resp model	probit	probit	probit	logit	probit	probit	probit
Airline dummies	yes	yes	yes	yes	yes	yes	yes
Adj R^2 Statistic	0.6385	0.6597	0.6826	0.6826	0.7297	0.7842	0.8067
RMSE Statistic	0.0940	0.0912	0.0880	0.0880	0.0813	0.0726	0.0687
CV RMSE Statistic	0.0955	0.0934	0.0894	0.0904	0.0834	0.0756	0.0719
Wald Statistic	464.76	491.86	473.49	473.49	599.98	736.54	954.14
VIF Statistic	8.87	8.93	8.93	8.93	9.51	65.48	67.69
AIC Statistic	842	843	844	844	857	864	871
BIC Statistic	908	914	919	915	968	1,001	1,026
Nr Observations	609	609	609	609	609	609	609

Notes: DISTSD is the standard deviation of domestic route distances of a given airline/time, weighted by the number of flight frequencies on the route. Source: ANAC, with own calculations. Results (marginal effects) produced by the fractional response model of Papke and Wooldridge (1996); fractional heteroskedasticity probit estimation implemented utilizing the number of monthly revenue passengers by carrier to account for the variance of error. Airline dummies estimates omitted; adjusted R2 and RMSE statistics extracted from an equivalent least-squares dummy-variables estimator (LSDV); CV RMSE is the RMSE calculated from a 5-fold cross-validation procedure; p-value representations, ***p < 0.01, **p < 0.05, *p < 0.10.

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