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Duopoly Competition between Airline Groups with Dual-brand Services - The case of the Australian domestic market

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ABSTRACT: The Australian aviation industry achieved substantial growth after the abolition of the "two-airline-policy" in 1990. With Virgin's purchase of Tiger Airways, a new duopoly between two airlines groups, each consisting of a full service airline (FSA) and a low cost carrier (LCC), emerged in the domestic market. In this study, we analyze the pricing dynamics among the four airlines of the duopoly groups, using panel data of online fares on the four most travelled routes in the domestic market. Our empirical results suggest that market segmentation allows the FSAs to charge significantly higher prices than the LCCs. Still, there is clear evidence of competition within and across the market segments, and the airlines' pricing responses are asymmetric. Virgin's price responses to Qantas and Jetstar are moderate. In comparison, more than one third of Qantas's fare changes and less than half of Jetstar's fare charges are in response to Virgin's fare adjustments in the previous period. Despite Qantas and Jetstar's large market share, after lengthy and costly price wars in previous years, the Qantas group still responds to Virgin as if competing with an entrant. All four carriers adopt revenue management practices, but the pricing of Qantas and Jetstar does not seem to be coordinated. Our study identifies a complex competition pattern between airline groups offering dual-brand services, and suggests that the Australian domestic market has not reached a stable equilibrium.

KEYWORDS: ***Australian domestic market, airline pricing, competition***

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1. Introduction

Air transportation not only contributes to passengers' wellbeing and logistics services, but also provides essential inputs to economic activities in other sectors such as tourism, trade, investment, and supply chain activities. It is very important for an economy to have access to high quality aviation services at competitive cost levels. This is particularly the case for Australia, where passengers rely almost exclusively on aviation to reach the rest of the world. In the domestic market, there are often long distances between populations and economic centers (Donehue and Baker 2012). The plan to link major cities with high-speed rail, despite the extensive policy debates and numerous studies carried out in the past half a century, remains on paper. It is important for Australian policy-makers to ensure that the nation has a well-performing aviation industry.

However, it has not always been clear what the optimal industry policy is and the aviation market in Australia has undergone dynamic changes. Douglas (1993) claimed that the Australian domestic market is a natural duopoly, which means the market is too small relative to the cost structures of the airlines, to support three major airlines operating jet aircraft. Douglas argued that as long as the incumbent match the price reductions of an entrant, the new airline's attempts to increase the market share by price reduction will fail and this will only lead to losses for both the new and existing airlines. This may have justified Australia's earlier "two airline policy," which mandated a duopoly between Ansett and Trans Australia Airlines (acquired by Qantas in 1992). Following the successful deregulation of the U.S. domestic aviation market, Australia abolished the two airline policy under the Airline Agreement Termination Act in 1990, along with many restrictions and regulations regarding prices, control of flight routes, and carrying capacity, and new airlines were allowed to enter all domestic routes (Forsyth 1998). The first low cost carrier (LCC) Compass I was established in 1990 but quickly failed. Compass II commenced operations in 1992 but collapsed in 1993. The entry of Compass triggered price wars in the domestic market and airfares became cheaper and the airlines reported major losses for the first half of the year. (Douglas 1993). Impulse Airlines was established 1992 and operated between 1994 and 2004. It was merged with Qantas and ceased operation in 2004 after the launch of Jetstar, an LCC owned by Qantas. In 2000, Virgin Blue entered the market with a low cost model, and filled the market gap caused by the failures of Compass I and Compass II (Forsyth 2003a).

The oligopoly market structure did not last very long, however. Shortly after the entry of Virgin Blue, Ansett went bankrupt, which gave Virgin Blue an opportunity to quickly expand its network (Whyte et al. 2012). With growth of 300% in passenger numbers in its first three years, Virgin Blue became the second largest carrier in Australia (Whyte et al. 2012). The market soon again evolved toward a duopoly between Qantas and Virgin, albeit in a different from. To compete with the rising Virgin

Blue, Qantas created a low cost subsidiary, Jetstar, in 2003, under what is known as the airline-within-airlines (AinA) strategy in the industry. Over time, Virgin Blue gradually shifted away from the LCC model by introducing priority check-in, in-flight entertainment, and meals and beverages for its premium passengers to capture the corporate and government markets (Whyte et al. 2012). It also created a frequent flyer program and eventually became a full service airline (FSA) and rebranded itself as Virgin Australia in 2012. In 2013, Virgin purchased 60% equity in Tiger Airways Australia, another major LCC in Australia. Tiger Airways, which was renamed Tigerair, became 100% owned by Virgin in 2014 after Virgin acquired the remaining 40% stake from Singapore airlines. As a result, the domestic market has returned to the duopoly market structure, this time between two airline groups: the Qantas group (FSA Qantas plus low cost subsidiary JetStar) vis-à-vis the Virgin group (FSA Virgin Australia plus low cost subsidiary Tigerair).

The Australian aviation market is now far more liberal than in the days of the "two airline policy" before the 1990s. Although there has been some debate on foreign investment and subsidies, the barrier to establishing an airline in Australia is generally low and foreign companies can compete in the domestic market through local subsidiaries. Nonetheless, the regulator has been cautiously maintaining sufficient competition in the market. For example, the proposed merger between Qantas and Air New Zealand in 2004 was rejected by both the Australian Competition and Consumer Commission and the New Zealand Commerce Commission, mainly due to the concern that competition may be reduced. The airline industry is not perfectly contestable. Although fierce competition between Qantas and Virgin has been observed, it is unclear whether sufficient competition can be maintained between two dominant airline groups that have a long history of multi-market contact.[1] Thus, it is important for policy makers and industry practitioners to develop a good understanding of the market dynamics in the era of the "new duopoly."

A study of the Australian market will also contribute valuable insights to the aviation literature. Although the issues of product line choice and multiproduct competition have been extensively discussed in the economics and management literature (Gilbert and Matutes 1993; Porter 1980, 1996; Klemperer and Padilla 1997; Johnson and Myatt 2003, 2006), few studies have empirically analyzed these strategies in the aviation industry. In fact, the previous attempts of FSAs to introduce low cost brands using the AinA strategy were largely unsuccessful in North America and Europe until a few carriers in the Asia-Pacific, notably Qantas, managed to sustain such dual-brand operations (Morrell 2005; Graham and Vowles 2006; Gillen and Gados 2008). Homsombat et al. (2014) analyzed route entry and pricing patterns during 2005-2012, when Virgin alone fought against the Qantas/Jetstar group and other rivals including Tiger Airways. Such "asymmetrical" competition is clearly different

[1] Previous empirical studies have found that that multimarket contact between airlines may lead to reduced competition and high fares. See for example, Evans and Kessides (1994), Gimeno (1999), Zou et al. (2012).

from a duopoly between two airline groups that both have dual-brand operations (i.e., full service and low cost services jointly provided). The aviation industry is yet to understand the market dynamics of such a new market structure. This is an important issue because many Asian carriers are experimenting with such a strategy (Fu et al. 2015).

In this study, we aim to fill these gaps in the literature by analyzing the price competition between the two duopoly airline groups in the four most densely travelled routes in Australia. Unlike most studies that use the average fares available from industry databases *ex post* (Berry 1992; Dresner et al. 1996; Windle and Dresner 1995, 1999; Boguslaski et al, 2004.Goolsbee and Syverson 2008; Wang et al. 2014; Fu et al. 2015), in this study air fares are collected online prior to the flight departure. This allows us to capture the dynamic pricing behavior of the airlines over time. Hence, our study not only identifies the competition patterns among airlines, but also offers insights into the revenue management practices in a new setting of dual-brand marketing. Our study obtained a number of interesting empirical results. First, there is clear market segmentation, which allows the FSAs to charge significantly higher prices than the LCCs. Moreover, the duopoly between the two airline groups maintains competition among the carriers, whose fares changes are met by the price responses of rival airlines. Second, the airlines' price responses are asymmetric. Despite Qantas and Jetstar's dominant market share, the airline group does not command price leadership. Instead, despite Virgin's moderate price reactions, Qantas and Jetstar adjust their prices significantly in response to Virgin's pricing dynamics. Although the Qantas group gave up defending its 65% target market share after costly price wars in 2014-2015, it still responds to Virgin as if competing with an entrant to its controlled territory. The Australian domestic market has not reached equilibrium and cannot be characterized by a leader-follower model. Third, there is significant price volatility for all airlines, with a general trend of price increases approaching the flight departure times. This suggests that the airlines in the Australian domestic market, FSAs and LCCs alike, are applying revenue management in their pricing decisions. However, there is no strong evidence of price coordination between Qantas and Jetstar, although studies have identified clear cooperation in their route entry. This suggests that while there is strategic coordination between the two brands, their daily operations remained largely independent, a feature which probably explains the success of the AinA strategy in Australia.

The rest of this study is organized as follows. Section 2 provides a brief background of the Australian aviation market and the alternative approaches that have been used to analyze airline competition. Section 3 introduces the empirical models and estimation results. The last section summarizes and concludes.

2. Background

Despite its relatively small population, Australia's aviation industry is well developed. The aviation industry contributes more than $30 billion per annum to the national economy, or 2% of Australia's GDP. More than 250,000 people are employed in the industry, either directly by airlines and airports, or indirectly along the industry value chain such as in the areas of training, maintenance, and sales (The Australian Aviation Associations Forum 2016). The domestic aviation market has recorded healthy growth over the past two decades. As shown in Figure 1, the number of revenue passengers carried in the domestic market increased from 28 million in 1995 to 58 million in 2015. During the same period, revenue passenger kilometers (RPK) increased from 26 to 68 billion, whereas the number of aircraft departures only increased by 11%. On average, over time more passengers are flying longer distances on larger aircraft. In 1995, the average flight stage length in the domestic market was 604 km and the number of domestic passengers per flight was 47. By 2015, these numbers had increased to 903km and 91, respectively.

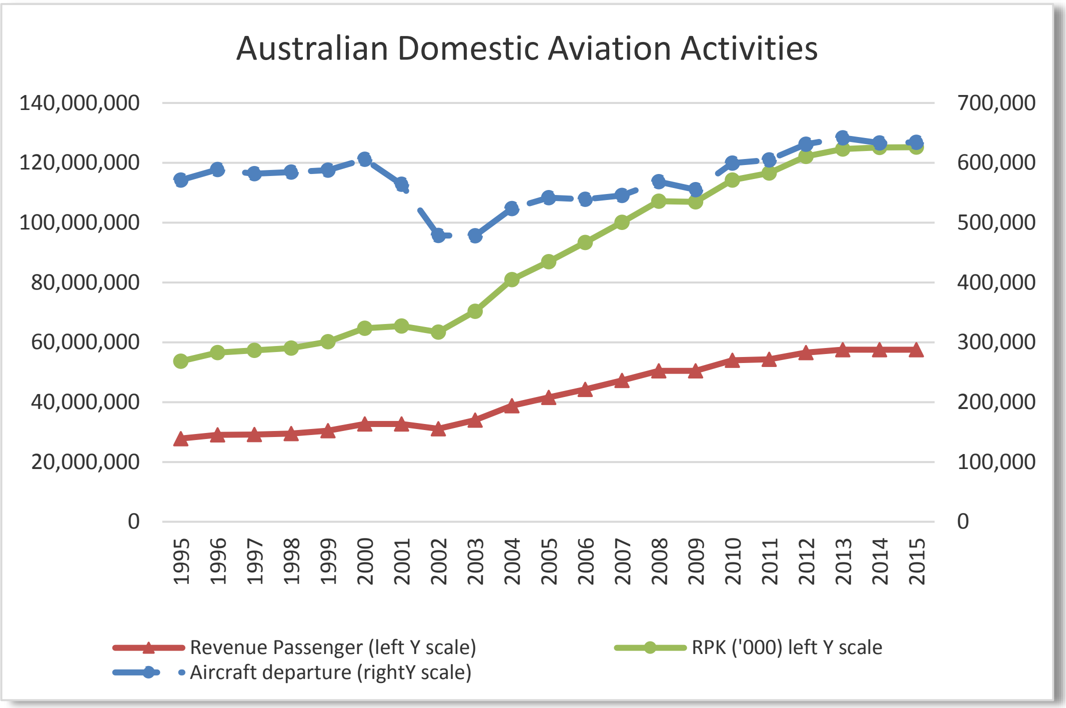

Figure 1. Australian Domestic Airline Performance Indicators (1995-2005)
Source: BITRE 2016

Much of the traffic is concentrated in the largest cities and international gateways. Table 1 reports the operational statistics for the top 30 most travelled routes in the domestic market for the financial year ending June 2016, which jointly accounted for 79% of the national passenger numbers and 80% of the

RPKs. The load factors are reasonably high largely because of the strong demand and sharp price competition in general.

Table 1. Top 30 Routes in the Australian Domestic Market (financial year 2016)
Source: BITRE 2016

Rank	City-Pair	Revenue Pax	Available Seats	LF %	A/C Trips
1	Melbourne - Sydney	8,796,220	10,634,203	82.7	59,593
2	Brisbane - Sydney	4,608,116	5,682,060	81.1	35,664
3	Brisbane - Melbourne	3,438,690	4,329,938	79.4	26,007
4	Gold Coast - Sydney	2,702,341	3,164,392	85.4	18,421
5	Adelaide - Melbourne	2,362,739	2,995,355	78.9	19,195
6	Melbourne - Perth	2,121,994	2,638,271	80.4	11,906
7	Gold Coast - Melbourne	1,898,578	2,299,293	82.6	12,344
8	Adelaide - Sydney	1,869,800	2,339,897	79.9	14,300
9	Perth - Sydney	1,760,030	2,189,274	80.4	9,146
10	Hobart - Melbourne	1,526,148	1,908,114	80.0	12,051
11	Brisbane - Cairns	1,333,793	1,607,275	83.0	10,037
12	Cairns - Sydney	1,075,721	1,285,725	83.7	7,467
13	Brisbane - Perth	1,000,679	1,243,130	80.5	5,801
14	Canberra - Melbourne	1,000,550	1,419,863	70.5	10,742
15	Brisbane - Townsville	983,907	1,335,218	73.7	9,018
16	Canberra - Sydney	948,981	1,357,667	69.9	17,430
17	Launceston - Melbourne	908,849	1,185,102	76.7	8,937
18	Adelaide - Brisbane	813,875	1,084,677	75.0	6,748
19	Cairns - Melbourne	802,231	962,784	83.3	5,155
20	Brisbane - Mackay	700,013	959,930	72.9	7,766
21	Adelaide - Perth	616,617	823,522	74.9	5,725
22	Hobart - Sydney	583,492	706,961	82.5	4,363
23	Brisbane - Rockhampton	572,318	797,249	71.8	9,524
24	Brisbane - Canberra	562,033	764,327	73.5	5,885
25	Brisbane - Newcastle	556,576	736,120	75.6	6,094
26	Karratha - Perth	551,168	966,154	57.0	7,515
27	Sunshine Coast - Sydney	513,619	619,935	82.9	3,594
28	Melbourne - Newcastle	439,186	550,908	79.7	3,115
29	Melbourne - Sunshine Coast	427,132	503,847	84.8	2,832
30	Brisbane - Darwin	402,798	515,466	78.1	3,133

The healthy growth of the aviation market can be partly attributed to Australia's resilient economy and the deregulation of the aviation industry. Prior to the 1990 Airline Agreement Termination Act, for four decades Australia's domestic market was governed by the "two airline policy," which ensured a duopoly between Ansett and Trans Australia Airlines. The two airlines served all of the major domestic routes and some regional routes with identical planes, schedules, and prices. As a result, each airline held approximately 50 percent of the market share (Quiggin 1997). The main criticisms of this policy included low productivity, high costs, high air fares, and limited quality service choices for consumers. Since the abolishment of the two airline policy, the Australian domestic airline sector has been largely deregulated, except for international air transport to and from Australia, which is still subject to bi-lateral agreements (Kain and Webb 2003). It is well recognized that deregulation and liberalization are likely to promote competition and efficiency in the aviation market (Fu et al. 2010). Indeed, numerous benefits of deregulation have been identified, including reductions in the average and discount fares as a result of more vigorous competition, increased flight frequency, increased domestic passenger numbers, better service, and improved on-time performance (BTCE 1995). The policy on foreign investment in Australia's aviation industry has been further liberalized. Formal approval by the Foreign Investment Review Board is usually not necessary, although foreign ownership in domestic airlines was capped at 25% for individual foreign ownership and 35% for total foreign ownership. In 2009, foreign ownership restrictions were removed for domestic airlines, although a cap of 49% is still imposed on international airlines. Since the late 1990s, all major airports have been privatized, and formal price regulation has been replaced by a "light-handed-regulation" (Forsyth 2002, 2003, 2004). In general, the new airport regulation regimes have performed well and airlines and airports have been able to agree on most commercial terms after some expensive litigation (Forsyth 2008, Littlechild 2012, Yang and Fu 2015).

Despite the successful outcomes resulting from deregulation and the liberal market conditions, it cannot be assumed that there has always been sufficient competition in the market. Apart from the short-lived Compass I and Compass II and the entry of Impulse, for most of the 1990s, the two incumbent airlines, Qantas and Ansett, did not face any challenges by new competitors until the emergence of Virgin Blue in 2000. The entry of Virgin was soon followed by the collapse of Ansett, which promoted antitrust agencies in Australia and New Zealand to reject the proposed merger between Qantas and Air New Zealand because of competition concerns. Although Virgin and Qantas have engaged in fierce price competition, it is unclear whether the airlines compete aggressively when the market is again dominated by two duopoly airline groups. Indeed, although there is a rich body of literature on airline competition, few studies have examined the case of airline groups offering both full service services and low cost services. Price discrimination is traditionally seen as one of the sources of price variation and in certain cases evidence of market power, especially in the airline industry (Borenstein 1985). Increased concentration may confer market power on airlines, and thus lead to price discrimination and dispersion (Borenstein 1989; Stavins 2001). These results suggest that there would have been reduced competition following Virgin's acquisition of Tiger Airways. However, other studies have dismissed the relationship between concentration and price dispersion (see Mantin and Koo 2009). The effects of concentration have produced mixed results in the airline industry, making it hard to develop effective antitrust policy recommendations (Zhang and Round

2009). Empirical studies on the aviation industry have also found that changes in the demand attributes and product differentiation have interactive effects on airline competition, especially in markets with LCC presence (Windle and Dresner 1995, 1999; Bilotkach et al. 2010, Mantin and Koo 2009, Fu et al. 2011, 2015). However, although the performance of airline alliances has been studied for FSAs (Oum et al. 1996, 2000, 2001; Oum and Zhang 2001; Bilotkach et al. 2013), few studies have analyzed airline group competition involving LCCs. This study aims to contribute to the air transport literature by filling this gap in the research and provide a better understanding of the Australian domestic market.

3. Data and methodology

In this section, we first present the data collection methods and some descriptive estimates carried out with fixed effect models. This is followed by an estimation using a GMM/IV panel VAR approach.

3.1. Data collection and descriptive estimates

To capture the market dynamics among the airline groups, online pricing data for the airlines were extracted from www.webjet.com.au, a popular online booking website in Australia. Mumbower et al. (2014) pointed out that the Internet has become an important channel for airlines, which has made it much easier for consumers to compare prices across multiple competitors. At the same time, airline companies can easily check the behavior of consumers and respond with appropriate pricing strategies to maximize their profits (Moreno-Izquierdo et al. 2015). The price data are on one-way airfares on the four most heavily travelled domestic routes in Australia, namely, Sydney-Melbourne, Sydney-Brisbane, Melbourne-Brisbane, and Sydney-Gold Coast, which currently account for about one third of the Australian domestic market. In many other markets, roundtrip flights almost always cost less than the sum of the two one-way trips on the same route. In Australia, the airfare on many domestic routes is simply the sum of the two one-way prices. Therefore, we only extract one-way airfares for the aforementioned routes. The period of data collection ran from 02/05/2016 to 29/05/2016. On each morning at around 7 am during this period, the lowest prospective airfares before 9 am, between 9 am to 6 pm and after 6 pm, on the 28th day, 21st day, 14th day, 7th day, and the next day from the observation day for each of the four airlines were recorded. For example, on the first observation day 02/05/2016, the price information on 29/05/2016, 22/05/2016, 15/05/2016, 08/05/2016, and 03/05/2016 was gathered. On the second observation day 03/05/2016, the airfare data on 30/05/2016, 23/05/2016, 16/05/2016, 09/05/2016, and 04/03/2016 were collected. This process was not completed until 29/05/2016, when the price data on 25/06/2016, 18/06/2016, 11/06/2016, 04/06/2016, and 30/05/2016 were extracted. Similar data collection methods have been used in studies on online pricing patterns (see, for example, Bilotkach et al. 2010, Mumbower et al. 2014, and Bilotkach et al. 2015). Although online databases are good representatives of the airline real-time prices that are available to consumers, it should be noted that there may be slight variation in prices when consumers actually purchase tickets at different times from our observation times, or purchase them from another website.

Table 2 reports the "best discount" average fares and standard deviations for the four airlines on four routes collected 28 days, 21 days, 14 days, 7 days, and 1 day before departure. In general, the prices tend to increase as the departure date approaches. For most of the time, Qantas tends to charge the highest prices on the same route, but one day before the departure, Virgin's prices often overtake those of Qantas. In general, however, the prices charged by Qantas and Virgin are comparable, and are higher than those offered by the LCC brands Jetstar and Tiger.

Table 2. Average Fares Charged by Airlines on Different Routes (standard deviation in parentheses)

		28 days	**21 days**	**14 days**	**7 days**	**1 day**
Sydney-Melbourne	Qantas	159.38 (24.19)	159.90 (22.55)	163.69 (25.94)	172.86 (30.66)	213.02 (61.15)
	Virgin	136.73 (19.17)	139.31 (19.91)	145 (28.47)	162.90 (34.47)	200.76 (62.91)
	Jetstar	62.69 (22.36)	65.40 (22.80)	66.83 (22.73)	75.43 (30.77)	110.46 (51.29)
	Tiger	68.82 (22.37)	72.71 (18.81)	80.52 (26.56)	83.75 (27.09)	122.01 (54.75)
Sydney-Brisbane	Qantas	153.67 (30.17)	161.10 (23.52)	164.28 (25.96)	158.92 (14.31)	177.43 (66.97)
	Virgin	128.40 (33.95)	129.45 (39.02)	140.50 (34.79)	142.25 (28.55)	180.94 (63.50)
	Jetstar	80.34 (30.68)	84.30 (31.94)	93.61 (34.71)	103.56 (37.05)	140.42 (60.95)
	Tiger	62.82 (31.02)	67.54 (30.35)	88.13 (46.41)	94.27 (54.78)	126.89 (55.32)
Melbourne-Brisbane	Qantas	194.06 (31.56)	194.29 (26.24)	203.83 (27.41)	202.48 (17.53)	213.35 (38.23)
	Virgin	159.55 (38.73)	158.55 (35.29)	169.35 (42.09)	183.52 (37.53)	216.13 (79.49)
	Jetstar	106.84 (25.79)	111.57 (24.59)	115.14 (32.51)	122.93 (36.39)	161.50 (67.51)
	Tiger	86.15 (42.68)	88.39 (23.76)	96.11 (35.31)	104.88 (37.56)	156.18 (59.05)
Sydney-Gold Coast	Qantas	123.97 (24.12)	129.48 (28.77)	132.52 (31.74)	134.39 (30.01)	149.67 (48.59)
	Virgin	110.48 (29.64)	109.36 (21.89)	118.12 (28.58)	124.37 (35.58)	155.67 (71.25)
	Jetstar	60.45 (24.36)	65.24 (24.65)	66.16 (26.90))	70.23 (21.87)	96.85 (43.98)
	Tiger	55.83 (29.05)	64.35 (29.83)	72.90 (36.69)	70.12 (35.04)	101.17 (48.59)

To test these patterns formally, we first consider a fixed effects model to characterize the fares along several dimensions. To set the stage for the estimates presented below, we start with a basic specification given by:

(1) $$fare = \beta_0 + \sum_j \beta_j C_j + \delta_{route} + \delta_{day} + \delta_{time} + \varepsilon ,$$

where the dependent variable is the fare of carrier *i* on route *r* charged *w* days before departure at time *t*; C_j are dummy variables for *j* = *Qantas; Virgin; Jetstar* indicating fares of carrier *j* and zero otherwise, with the reference base being Tigerair. The variables δ_{route}, δ_{day}, and δ_{time} constitute a route fixed effect, and day and time fixed effects, respectively. We cluster standard errors at the route level to make their estimation robust to serial correlation and heteroskedasticity (see Bertrand et al. 2004) among fares within the same route. Our parameters of interest are β_1, β_2, and β_3, which capture the average differences in fares charged by Qantas, Virgin, and Jetstar in comparison to Tigerair.

In addition to providing average fare differences, we aim to characterize how the fares vary approaching flight departure. This is achieved by considering a specification that allows the effect of C_j in equation 1 to vary with days, so that Eq. 1 is rewritten as:

(2) $$fare = \beta_0 + \sum_j \sum_k \beta_{jk} C_j \, depart_k + \delta_{route} + \delta_{day} + \delta_{time} + \varepsilon ,$$

where $depart_k$ are dummy variables that take the value of 1 if the departure occurs in 27, 21, 14, 7, and 1 day respectively, and zero otherwise. The coefficients β_{jk} capture the average fare differences in comparison to the fare charged by Tigerair one day before departure. The OLS estimation results for Equations (1) and (2) are reported in Table 3.

Table 3. Estimation Results for Equations (1) and (2)

Variables	Eq(1)		Eq.(2)	
	Coef.	t-stat	Coef.	t-stat
Qantas	.729***	73.64		
Virgin	.600***	62.89		
Jetstar	.062***	6.35		
Qantas 28 days			.309***	14.42
Qantas 21 days			.333***	15.51
Qantas 14 days			.361***	16.62
Qantas 7 days			.371***	17.27
Qantas 1 day			.465***	21.6
Virgin 28 days			.134***	6.48
Virgin 21 days			.142***	6.83
Virgin 14 days			.204***	9.84
Virgin 7 days			.270***	12.99
Virgin 1 day			.443***	21.11
Jetstar 28 days			-.456***	-21.4
Jetstar 21 days			-.400***	-18.85
Jetstar 14 days			-.365***	-17.03
Jetstar 7 days			-.278***	-13.03
Jetstar 1 day			0.002	0.08
Tiger 28 days			-.580***	-26.51
Tiger 21 days			-.492***	-22.43
Tiger 14 days			-.387***	-17.7
Tiger 7 days			-.345***	-15.57
Route fixed effect	X		X	
Weekday fixed effect	X		X	
Time fixed effect	X		X	
Observations	5783		2379	

Note: *** stands for p<1%. Standard errors are clustered at municipal level.

Almost all of the coefficient estimates have the expected sign and are significant. With the fixed effects of route, day, and time controlled, there is a clear sign that the fares of all carriers increase toward departure day, which is a typical sign of revenue management. Over the booking period, Qantas and Virgin consistently charge higher prices than Tigerair, whereas the fares of the two LCCs are comparable. The significant price differences between the FSAs and LCCs confirm the expected product differentiation between the two segments, as observed in other aviation markets (Fu et al. 2011).

3.2. A GMM/IV Panel VAR approach

Although the fixed effects models reveal some typical patterns in fares, the estimation may be subject to estimation bias due to the endogenous fare competition among the carriers. In this section, we consider a panel VAR model with $Y_{it} = [Virgin_{it}, Qantas_{it}, Jetstar_{it}, Tiger_{it}]'$ as our fare vector of k endogenous variables for routes i at time t. The reduced form dynamic relationship among our endogenous variables can be described by:

(3) $$Y_{it} = A_{0i} + A(l)Y_{t-1} + u_{it} ,$$

where A_{0i} is a $k \times 1$ vector of time-invariant route-specific intercepts, and $A(l)$ are $k \times k$ matrices of lagged coefficients, $A(l) \equiv \sum_{j=1}^{p} A_j l^{j-1}$, that collect the own- and cross-effects of the *l*th lag of the dependent variable on their current observations. Finally, u_{it} is a $k \times 1$ vector of idiosyncratic disturbances where $(u_{it}) = 0$, $E(u_{it}u_{it}') = \Sigma_u$, with Σ_u being a non-singular matrix and $E(u_{is}u_{it}') = 0$ for $t \neq s$.

The route-specific intercepts A_{0i} in equation (3) are likely correlated with the error term, and thus OLS estimation may lead to biased coefficients. A common strategy to deal with this, particularly in settings where the sample size is large, is to implement a transformation in the model to eliminate the individual fixed effects and then use GMM estimation methods using lagged observations as instruments. We follow the approach in Arellano and Bover (1995) and rewrite (3) in terms of forward orthogonal deviations. That is, for every element $y_{it} \in Y_{it}$, let

(4) $$y_{it}^* = (y_{it} - \overline{y_{it}})\sqrt{\frac{T_{it}}{T_{it}+1}} ,$$

where T_{it} is the number of available future observations for route i at time t and $\overline{y_{it}}$ denotes the average. This kind of transformation has some advantages over simple first-differences (see, for example, Baltagi 2008 and Góes 2016). By using deviations from an average instead of from another observation, forward orthogonal deviations reduce data loss and are less hampered by the varying gaps between observations, as in the case of unbalanced panels. Following Holtz-Eakin et al. (1988), the instruments list is composed of observed realizations only, with missing observations substituted by zero.[2]

[2] These steps were structured in Abrigo and Love (2015), who also provided the computational routine used in this study. As detailed in Roodman (2009), from the hypothesis that instruments are orthogonal to the error term, the GMM estimator for A_j in (3) takes the form $\widehat{A}_j = (X^{*'}ZWZ'X^*)^{-1}(X^{*'}ZWZ'Y^*)$, where $Y^*$is a vector with transformed variables in the left-hand side of the model, X^* is a matrix with lagged transformed variables in its right-hand side, and W is a weighting matrix assumed to be non-singular, symmetric, and positive semi-definite, and chosen to maximize the efficiency of estimation.

To identify the structural shocks we need to impose one restriction on the covariance structure to orthogonalize the contemporaneous responses, and hence make Σ_u take the form of a lower-triangular matrix. In the Cholesky ordering, the LCCs and Qantas are set to have no contemporaneous effect on Virgin, while the latter is allowed to contemporaneously influence the former. By construction, this reduces the short-term effects of the LCCs and Qantas on Virgin. This approach is adopted because Virgin has aimed to further increase its market share in the domestic market, and is effectively the only competitor to the Qantas group. Alternative assumptions on contemporaneous effects are tested which do not lead to qualitatively different results.

To recover impulse response functions that characterize the price reaction dynamics, we rewrite equation (3) as $(l)Y_{it} = u_{it}$, where $B(l) = (I_k - A(l))$. As described in Lütkepohl (2005), if every eigenvalue in $A(l)$ is less than 1 in modulus, then $B(l)$ will satisfy the stability condition and be invertible. The calculated values $B(l)^{-1} = \Phi(l) = \sum_{j=0}^{\infty} \Phi_j l^j$ will then be the parameters of the moving average (MA) representation of our model, $Y_{it} = \Phi(l)u_{it}$, where

(5)
$$\Phi_j = \begin{cases} I_k, & j = 0 \\ \sum_{j=1}^{i} \Phi_{t-j} A_j, & j = 1,2, \ldots \end{cases}$$

Because the disturbances u_{it} are contemporaneously correlated, stochastic shocks to one variable are likely to be accompanied by shocks to other variables, which prevents us from drawing causal interpretations. However, the imposed Cholesky ordering allows the decomposition $\Sigma_u = P'P$, where P is also a lower-triangular matrix. It is then possible to orthogonalize the disturbances as $P^{-1}u_{it}$ (which will have the covariance matrix $P^{-1}\Sigma_u(P^{-1})' = I_k$) and transform the MA parameters into orthogonalized impulse-responses, $\Phi_i P$ iP. This way, the shocks to one variable will independently provoke dynamic responses in the other variables of the system.

The estimates of the VAR model depend on the choices of optimal lag length. We rely on the set of consistent moment and model selection criteria proposed by Andrews and Lu (2001) and recommendations for panel VAR models by Abrigo and Love (2015). The criteria of Andrews and Lu (2001) are based on Hansen's *J* statistic of over identifying restrictions and are analogous to various commonly used maximum likelihood-based model selection criteria such as the AIC, BIC, and HQIC. For our study, it is obtained that the models should be estimated using only one lag (Hansen's *J* statistic equals 26.424 for one lag and 10.658 for two lags). We also check the stability condition of our panel VAR estimates by calculating the modulus of each eigenvalue of the estimated model. According to Lütkepohl (2005) and Hamilton (1994), a VAR model is stable if all moduli of the companion matrix are strictly less than one. This implies that our panel VAR model is invertible and has an infinite-order vector MA representation, thus providing a known interpretation of the estimated impulse-response functions and forecast-error variance decompositions presented below. Figure 2 provides graphical evidence that the estimated values of the roots for the companion matrix are strictly smaller than one, which confirms the stability of the model.

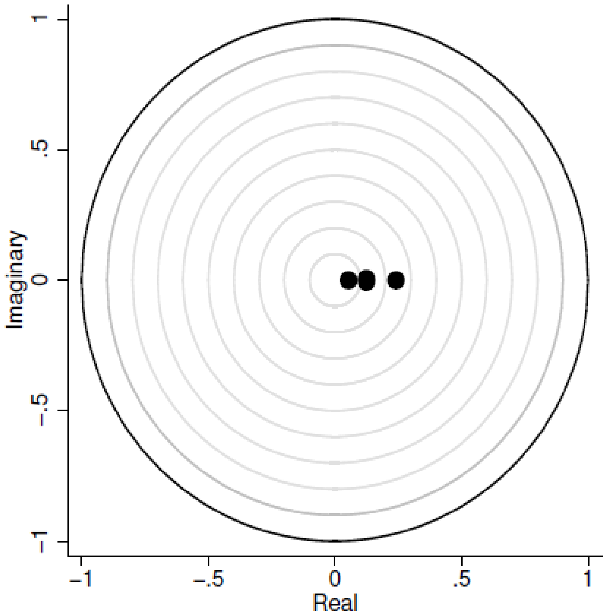

Figure 2. Roots of the Companion Matrix

In the main estimates of this study, we compute the impulse response functions (IRFs) and the variance decompositions (VDCs). IRFs describe the response of an endogenous variable over time to a shock in another variable in the system. VDCs measure the contributions of each source of shock to the (forecast error) variance of each endogenous variable, at a given forecast horizon. We start by presenting the IRFs for our four variables of interest, which are depicted in Figure 3. We note that the results from the estimated GMM/IV Panel VAR are the average responses of the endogenous variables to an exogenous shock in any variable after controlling for fixed characteristics. In addition, because our panel VAR is stable, the shocks eventually converge to zero, meaning that they are temporary and the time series eventually returns to its deterministic trend in the long-run.

For a better interpretation of the estimation results, the IRFs and VDCs are presented together in Figure 3 and Table 4. The columns of Figure 3 represent the responses of the endogenous variables (i.e., the fare vector Y_{it} to a shock of one standard deviation (SD) in each of the variables indicated in rows). For example, the first column contains the plots of the responses from Virgin to a shock of one standard deviation in each indicated variable (i.e., its own fare change, and the fare changes of Qantas, Jetstar, and Virgin, respectively). Accordingly, the second, third, and fourth columns represent the responses made by the other three airlines. The solid lines correspond to the median responses to the shocks in a 10 period horizon and the dashed lines are the 68% confidence interval. As expected, a positive shock to each of the four airlines' fares has a positive yet short-lived effect on their own (future) fares.

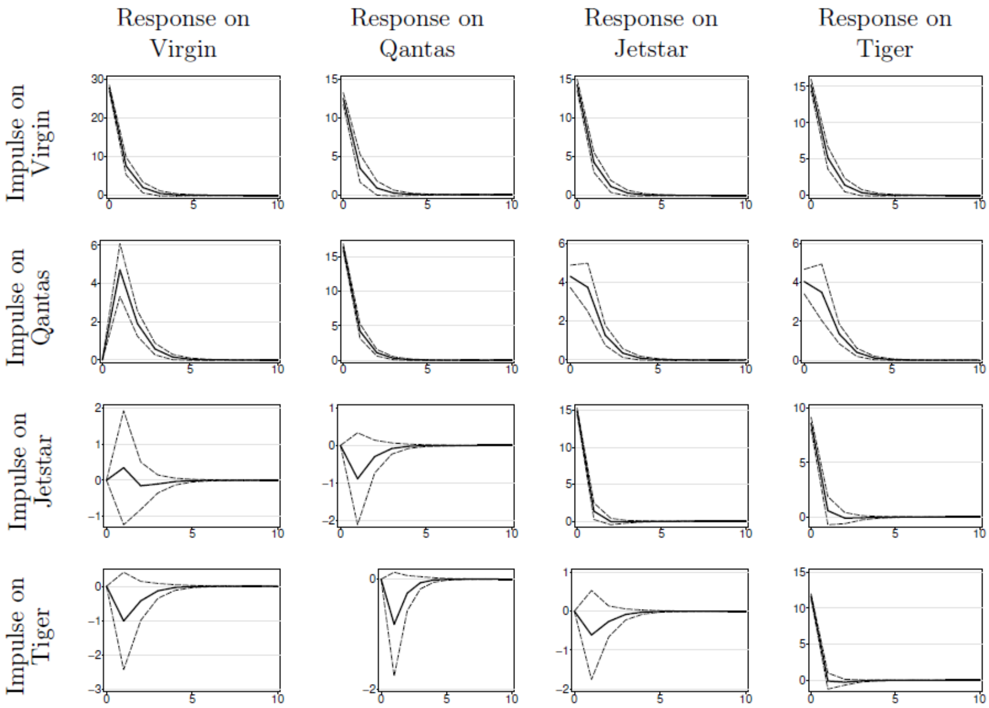

Figure 3. Impulse Response Functions of the Airlines

Note: Each column contains the plots of an airline's responses to a shock of one standard deviation in each indicated variable. The solid lines correspond to the median responses and the dashed lines are the 68% confidence interval.

To evaluate the relative cumulative contribution of each of the variables to the overall behavior of our model, forecast-error VDCs are performed as reported in Table 4. Each panel decomposes an airline's fare changes (variation in response variables) in response to the fare changes by the airlines in our sample (impulses on column variables). For example, line 1 in Panel A reports that on average, 97.25% of Virgin's price changes are due to its own changes in the last period, whereas 2.61%, 0.01%, and 0.12% of the fare changes can be ascribed to responses to the fare variations of Qantas, Jetstar, and Tiger in the last period, respectively.

Figure 3 and Table 4 reveal some interesting patterns concerning the fare dynamics on the four most densely travelled routes in the Australian domestic market. There appears to be strong competition among the airlines. The four charts in row 1 of Figure 3 suggest that Virgin's price variations are met by strong responses by other airlines. A one standard deviation fare change (impulse) by Virgin triggers the other airlines to change their fares (response) in the same direction by about $15 in the following period. Note that although Jetstar's responses are of similar magnitude to those of Qantas, they represent a more significant reaction in terms of percentage change because Jetstar's fares are generally much lower than those of Qantas. As reported in Panels B and C of Table 4, in the period immediately following Virgin's price changes (i.e., forecast horizon 1, or the first row in each panel), 36.7% and 46.3% of the fares changes by Qantas and Jetstar, respectively, are in response to Virgin's fare changes. Qantas's fare adjustments also lead to fare responses by the other airlines, and these changes are all statistically significant, albeit of smaller scale compared to the responses to Virgin's fare changes. Jetstar's fare adjustments lead to fare adjustments by Tiger but not the other carriers. Overall, there is clear evidence of fare competition among the airlines, both within the same segment (the full service and low cost travel sectors) and across segments (i.e., competition between Virgin and Jetstar).

Table 4. Variance Decomposition for the Four Airlines

Forecast horizon	**Impulse Variable**			
	Virgin	**Qantas**	**Jetstar**	**Tiger**
Panel A. Response on Virgin				
1	0.9725369	0.0261153	0.0001405	0.0012074
2	0.9683173	0.0301076	0.0001668	0.0014083
3	0.9679194	0.0304729	0.0001792	0.0014285
4	0.9678892	0.0304997	0.0001809	0.0014301
5	0.9678872	0.0305015	0.0001811	0.0014302
Panel A. Response on Qantas				
1	0.3669341	0.6298772	0.0017184	0.0014702
2	0.3669204	0.6295721	0.001902	0.0016056
3	0.3669162	0.6295529	0.001916	0.0016149
4	0.3669158	0.6295518	0.0019169	0.0016155
5	0.3669158	0.6295517	0.001917	0.0016155
Panel A. Response on Jetstar				
1	0.4625833	0.0681078	0.4685294	0.0007795
2	0.4624523	0.0710192	0.4656082	0.0009204
3	0.4624189	0.0712475	0.4653997	0.0009339
4	0.4624158	0.071263	0.4653863	0.0009349
5	0.4624155	0.0712639	0.4653854	0.000935
Panel A. Response on Tiger				
1	0.5185857	0.0574392	0.1496117	0.2743633
2	0.5185461	0.0606173	0.1484654	0.2723712
3	0.5184895	0.0609097	0.1483829	0.2722178
4	0.5184836	0.0609313	0.1483778	0.2722072
5	0.5184832	0.0609328	0.1483775	0.2722065

Note: Percent (in unitary values) of variation in the response variables (presented in each panel) to impulses on the column variables for five periods following the impulses.

The fare adjustment patterns are clearly asymmetric. There is asymmetrical competition across the market segments in that fare adjustments by the two FSAs trigger significant price changes by all the other airlines. In comparison, the fare changes by the LCCs only lead to price responses within the low cost sector. Tiger has been performing poorly in the Australian domestic market and was only acquired by Virgin recently. This probably explains why the other three airlines' price responses to Tiger are not statistically significant. However, Jetstar is a leading LCC with a significant market share. Although our findings are preliminary, our study of the main travel routes suggests more complex competition patterns among the airline groups compared to pure FSA-LCC competition. Another asymmetry is between the airline groups. Both Qantas and Jetstar respond to Virgin's fare adjustments with significant price adjustments (recall that 36.7% and 46.3% of the fare changes by Qantas and Jetstar, respectively, are in response to Virgin's fare changes in the last period). In comparison, only 2.6% of Virgin's fare adjustments are in response to Qantas and the response to Jetstar is not statistically significant. This is somewhat expected as the Qantas group has consistently dominated the market since the collapse of Ansett. Our results suggest that the large market share does not automatically give the Qantas airline group price leadership as in a leader-follower model. Instead, although the Qantas group gave up a target market share, it still treats Virgin much like an "entrant" into its territory. On the one hand, this suggests that substantial competition will be maintained in the market. On the other hand, this suggests that the current market probably has not reached equilibrium and market dynamics are expected in the future.

Finally, we did not observe a clear sign of pricing coordination between Qantas and Jetstar, although the airline group has been implementing a dual-brand strategy for over a decade. Qantas does not respond to Jetstar's price changes, whereas on average only 7% of Jetstar's fare adjustments are associated with Qantas's pricing behavior. Homsombat et al. (2014) and Zhang et al. (2015) found clear coordination of route entry decisions between the two brands, which suggests some strategic/long-term coordination. However, Jetstar has clearly tried to maintain some autonomy in its daily operations. For example, the subsidiary chose to establish its headquarter in Melbourne so that it can operate at arm's length from Qantas's headquarter in Sydney. This is probably an important factor in Qantas's success in adopting the AinA strategy despite the failures of many other airlines.

4. Summary and conclusion

Significant changes in the market structure and regulatory policies have occurred in the Australian domestic market in the past decades. Consistent with the literature, deregulation and airline competition have allowed the airline sector to achieve healthy growth. The Australian market also exhibits some unique features, notably the formation of airline groups that offer dual-brand services in both the FSA and LCC segments. It is not clear whether the formation of the new duopoly between the two airline groups, namely Qantas/Jetstar and Virgin/Tiger, will reduce the competition with increased market concentration. In this study, we analyze the pricing dynamics among the four airlines of the two groups in the four most travelled routes in the domestic market using panel data of airline fares collected online in 2016.

Our investigations confirm that there is clear market segmentation, which allows the FSAs to charge significantly higher prices than the LCCs. The duopoly between the two airline groups has maintained the competition between the airlines, whose fare changes are met by price responses from the rival carriers. On average, more than one third of Qantas's fare changes and less than half of Jetstar's fare charges are in response to Virgin's pricing adjustments in the previous period. About 6% and 15% of Tigerair's price changes can be ascribed to the pricing dynamics of Qantas and Jetstar. However, the price responses are asymmetric. Despite Qantas and Jetstar's dominant market share, the airline group does not enjoy price leadership. Instead, despite Virgin's moderate price responses, Qantas and Jetstar adjust their prices significantly in response to Virgin's pricing dynamics. Although the Qantas group has given up defending the 65% target market share after the costly price wars in 2014-2015, it still responds to Virgin as if competing with an entrant. The Australian domestic market has not reached equilibrium and future dynamics are expected.

We find significant price volatilities for all of the airlines, with a general trend of price increases approaching flight departure. This suggests that all of the airlines, FSAs and LCCs alike, have been utilizing revenue management in their pricing decisions. However, there is no strong evidence of joint price-setting between Qantas and Jetstar, although previous studies have identified clear patterns of route entry coordination. This suggests that while there is some high-level strategic coordination between the two brands, daily operations remain largely independent, which probably explains the airline group's success in using the AinA strategy.

Our empirical results suggest that there are complex competition dynamics between airline groups that offer both full and low cost services. However, it should be noted that we only analyze the case of the top routes in Australia over a short period. As more and more Asian airlines are setting up low cost subsidiaries, it is important to examine airline group competition in other markets with larger datasets. In addition, although our time series analysis reveals the airlines' pricing strategies over time, it would be useful to examine airline competition with more structured models. We hope our investigation will lead to extended studies on this important topic in the future, so that valuable insights can be offered to policy-makers and industry practitioners.

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