Understanding airline price dispersion in the presence of high-speed rail

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Abstract

This paper examines the price dispersion among China's "Big Three", namely, Air China, China Eastern and China Southern in the presence of high-speed rail (HSR). It has been found that HSR is positively and significantly associated with airline price dispersion on the long-haul routes, which may suggest that the presence of HSR can facilitate airline cooperation in setting prices and outputs, thereby leading to greater price dispersion. However, on the short-haul routes where HSR is highly substitutable, the HSR competition effect dominates, and smaller price dispersion is observed. All the market structure and competition variables included in this study support the conclusion that price dispersion is greater in more concentrated and more densely travelled markets. The contribution of airline cost to price dispersion is limited.

Keywords: price dispersion; high-speed rail; airline; competition; collusion

1. Introduction

The year of 2019 marks the tenth anniversary of the opening of China's first long-haul high-speed rail (HSR), the Wuhan-Guangzhou HSR. Ten years on, China has been a leader in transport development, particularly in the construction of HSR. By 2019, the total length of the HSR network in China had exceeded 35,000 km, accounting for more than 60% of the world total. It is expected that China's HSR network will continue to expand, reaching 38,000 km by 2025 and 45, 000 km by 2030 (NDRC, 2016). Lawrence et al. (2019) note that China is unique in many ways that make it suitable to develop HSR, including its fast economic growth, its large country size with long distances between North and South, and East and West, and the substantial population density. The presence of HSR not only has an impact on the rail industry but also affects other industries such as aviation, tourism as well as the patterns of urban development.

HSR fares in China are much lower than those in Japan and Europe. This has made this new transport mode quite affordable to almost all income groups. Its fast speed, comfort, convenience, safety, and punctuality have attracted both leisure and business travellers and enticed passengers from other transport modes. For example, Ren et al. (2019) found that travel demand has increased by 60% after the launch of the Chengdu-Chongqing HSR. In 2018, China's HSR carried 2 billion passengers (Global Times, 2019). It is expected that the HSR passenger traffic will continue to grow at a rate of more than 20% in the next few years.

There is no doubt that the presence of HSR has a significant impact on China's airline industry. Such impact is comprehensive and all-encompassing: airlines were forced to cut back on capacity on the routes with parallel HSR services and in extreme cases air services were completely eliminated (Zhang and Zhang, 2016). Despite this, China's air transport market still maintains a two-digit growth in the last decade and China has already been the world's second largest aviation market. In 2018, China's airline handled 611.7 million passengers (Zhang et al., 2020). It is widely believed that China will overtake the United States (US) as the largest air passenger market in the next decade or so and that the centre of gravity of the air transport industry will shift from the western hemisphere to Asia. Liu and Oum (2018) claim that Chinese carriers will soon become global leaders in terms of setting standards on the global air transport sector.

The impact of HSR on the competition and interaction between HSR and air transport has been well studied. A good survey of such studies can be found in Zhang et al. (2019). A large volume of literature reports that HSR has exerted downward pressure on airfares, flight frequencies, and air traffic (e.g., Wardman et al., 2002; Campos and de Rus, 2009; Albalate and Bel, 2012; Givoni and Dobruszkes, 2013; Dobruszkes et al., 2014; Albalate et al., 2015; Wan et al., 2016; Chen, 2017; Wang et al., 2018; Zhang et al., 2019). However, studies on the impact of China's HSR on airline pricing are relatively under-researched. Only a small number of studies have touched on this topic including Zhang et al. (2014, 2017, 2020) and Ma et al. (2019). Zhang et al. (2014, 2017, 2020) found that HSR is one of the most important determinants in suppressing market power in China's airline market. Ma et al. (2019) examined the airline routes along the Beijing–Shanghai HSR line. The authors found that both airfare and air demand fell significantly after the entry of HSR. In particular, economy-class airfares dropped more than business-class airfares.

Price dispersion is a much-debated topic in airline pricing literature. This topic is closely related to firms' pricing power, price discrimination, product differentiation and search cost concerning consumers, firms and regulators (Roma et al., 2014). Therefore, price dispersion is of great interest to economists. Significant variation in price dispersion across different carrier-routes is common (Borenstein and Rose, 1994). Borenstein (1985) and Holmes (1989) demonstrate that price dispersion can be expected to increase when a market moves from monopoly to imperfect competition and becomes less concentrated. Borenstein (1989) found that lower-end fares tend to be more responsive to competition than higher-end fares when a new entrant is present. That is, an airline's price to a particular consumer group depends on their elasticity of demand for air travel and cross-elasticity of demand among specific brands such as flight times and airlines (Borenstein and Rose, 1994). This effect has been labelled as the brand loyalty effect, which was also confirmed in Stavins (2001) and Giaume and Guillou (2004). However, on the other hand, traditional microeconomic theory predicts that price dispersion should decrease with competition. This is because as the market structure is close to perfect competition, a firm loses its ability to set prices above marginal costs. Therefore, increased competitive pressures make it more difficult for existing airlines to price discriminate between business and leisure passengers (Gerardi and Shapiro, 2009). This has been labelled as the monopoly effect. Further evidence was found in the UK-Irish market that price dispersion decreases with competition by Gaggero and Piga (2011).

HSR has been regarded as a close substitute for air, particularly on the short- and medium-haul routes. With the entry of HSR in the markets where air services are present, it is expected that airlines will respond and adjust their pricing strategies, which will lead to a change in the pattern of the price dispersion. This study attempts to reveal how price dispersion in China's aviation market has changed as a result of the presence of HSR as an effective competitor to the airlines. It should be pointed out that most of the existing literature studying price dispersion focuses on price discrimination and intra-firm price dispersion. Our study will mainly examine the interfirm price dispersion for its significant antitrust implications. The next section will review the relevant literature. Section 3 presents the data, the measurement for price dispersion and econometric models. Section 4 reports the results. The last section concludes.

2. A review of relevant studies on price dispersion

Although the law of one price theoretically exists in a friction-free for homogeneous goods where competition is prefect and consumer search cost is zero, price dispersion is ubiquitous across various homogeneous product markets, such as gasoline, automobiles, consumer electronics, and airlines (Zhao et al., 2015). The use of revenue management systems allows airlines to engage in inter-temporal price discrimination, and intra-firm price discrimination (Gallego and Van Ryzin, 1994; Talluri and Van Ryzin, 2004). The practice of price discrimination, i.e., offering multiple airfares for the same flight has been one of the sources of price dispersion (Borenstein, 1985). Zhang et al. (2018) studied the Australian domestic aviation market and found that airfares tend to increase as the departure date approaches. For most of the time, Qantas tended to charge the highest prices on the same route, but one day before the departure, Virgin's prices often overtook those of Qantas. The interfirm price dispersion actually decreases as the departure date nears.

Borentein and Rose (1994) note that the sources of airline price dispersion include price discrimination, market structure, population attributes, product attributes, and systematic and stochastic peak-load pricing. Hayes and Ross (1998) pointed out that price dispersion can be planned or unplanned as non-competitive and competitive forces can lead to price dispersion. Price discrimination is an example of an airline's careful plan to maximize profits when it possesses market power and has sufficient information about passengers' willingness to pay. Hayes and Ross (1998) contend that planned price dispersion is probably associated with higher market concentration, higher price mark-ups, and hub dominance. In contrast, price wars are a common phenomenon in the airline market (Zhang and Round 2018; Zhang and Round, 2011; Ma et al., 2019). A price war is likely a result of the lack of sufficient market power for airlines to sustain a price at a level above marginal cost (Hayes and Ross, 1998). In the imperfect monitoring models developed by Green and Porter (1984) and Abreu et al. (1986), periodical price wars are a result of the firms' inability to monitor other members' behaviour perfectly. Price wars are a solution to help maintain a cartel agreement. In all these cases, price dispersions caused by price wars are likely to be unplanned. Hayes and Ross (1998) also note that price dispersion arises in the airline industry due to its multiple product nature. Airlines adopt various profit maximization strategies that can lead to price dispersion not only across markets but also through time.

Successful collusion or cartel may reduce price variation (Stigler, 1961, 1964; Carlson and McAfee, 1983; Dana, 1999; Harrington and Chen, 2006). Connor (2006) notes that to reduce the number of collusive dimensions, cartels usually will adopt "common delivery charges, standard price premiums for alternative grades, payment schedules, price protection clauses in supply contracts, and so forth" (Connor, 2006, p.336). Empirical findings in Dahlby and West (1986) and Borenstein and Rose (1994) support this view. Athey et al. (2004) demonstrated that the optimal symmetric collusion is characterized by price rigidity and the absence of price wars on the equilibrium path. Bolotova et al. (2008) argue that an increase in the mean price and a decrease in the price variance may indicate the existence of collusive behavior in markets, although the price variance decrease without the presence of the mean price increase may also suggest a presence of collusive agreement.

In the last two decades, the Internet has become a popular platform for product sales and Internet penetration in airlines is significant and substantial. For many airlines, particularly the low-cost carriers (LCCs), the share of airline ticket distribution through the Internet has been more than 50%. There has been much literature examining the impact of the Internet on airline price dispersion. Roma et al. (2015) note that the traditional microeconomic view would argue that the Internet and the e-commerce could foster competition and thereby led to pricing consistent with the prediction of the 'law of one price'. This view has received support in studies such as Clemons et al. (2002), Baye et al. (2004), Gerardi and Shapiro (2009) and Dominici (2009). However, Roma et al. (2015) find that price dispersion differs greatly across different types of online channels. Price dispersion is found to be higher on the routes with higher competition. Orlov (2011) also finds that decreases in search costs associated with Internet penetration result in an increase in within-firm (intra-firm) price dispersion. However, Internet penetration does not affect interfirm price dispersion. This is in contrast to Verlinda and Lane (2004) in which interfirm price dispersion was found to increase with Internet access increases. Sengupta and Wiggins (2014) report that after controlling for ticket characteristics, online buyers paid about 11 percent less than offline buyers. There is tentative evidence showing that increased online shares decrease price dispersion.

As with the Internet that normally facilitates competition and puts downward pressure on prices (Orloy, 2011), HSR has been confirmed to have a significant effect on airfares in most studies (Zhang et al., 2019). However, it is not known if the presence of HSR increases or decreases airline price dispersion. To the best of our knowledge, intertemporal price dispersion of Chinese airline prices caused by HSR was only briefly discussed by Su et al. (2019). No other research has touched on this issue so far, let alone the study of interfirm price dispersion. This paper aims to fill this literature gap.

3. Methodology

3.1 Data

Our dataset was constructed using information from the IATA Airport Intelligence Services database. The dataset contains monthly domestic airline-route information on the origin, destination, monthly economy-class airfares and monthly number of passengers by routes and carriers, spanning from April 2007 to December 2016. Based on the Statistical Data on Civil Aviation of China (CAAC, 2015), we selected 280 most heavily travelled routes with each carrying at least 300,000 passengers in 2014.[1] The top 280 accounted for about two-thirds of the country's total traffic volume. Routes carrying less than 300 passengers a month were dropped from the dataset. There were 42 airlines operating on our sample routes.[2] However, since our analysis focuses on price dispersion of the "Big Three", we construct the dataset by setting the individual observation as a specific route simultaneously served by a pair of airlines of the "Big Three". Data of other airlines are used to calculate route-level control variables such as the Herfindahl-Hirschman Index (HHI), the number of carriers, etc. The unbalanced panel data contains 50,128 carrier-pair-route-time level observations.

Figs. 1 and 2 depict an overview of our sample markets during the study period 2007-2016. Fig. 1 shows that the number of airlines operating on the sample routes doubled from 2007 to 2016 thanks to further deregulation in China's domestic market. Fig. 2 shows that "Big Three" gradually lost their market share on the sample routes due to the new entrants over time. It is apparent that competition in the aviation market was more intense in 2016 than in 2007. This provides a good opportunity for us to study the price dispersion issue.

[1] The number of passengers is the sum of the movements of both directions of the route.
[2] The list of airlines contained in our sample is presented in Appendix.

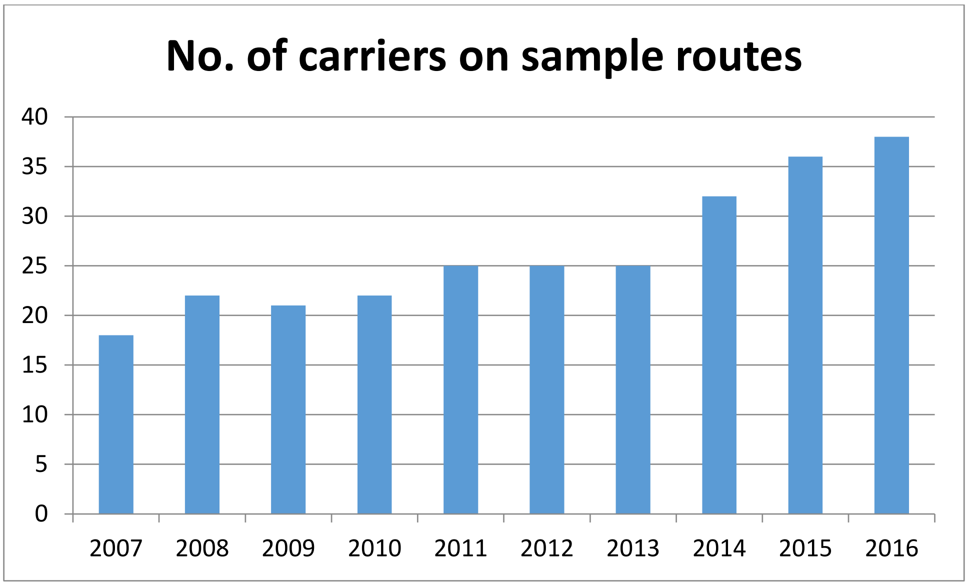

Fig.1 Number of carriers on sample routes

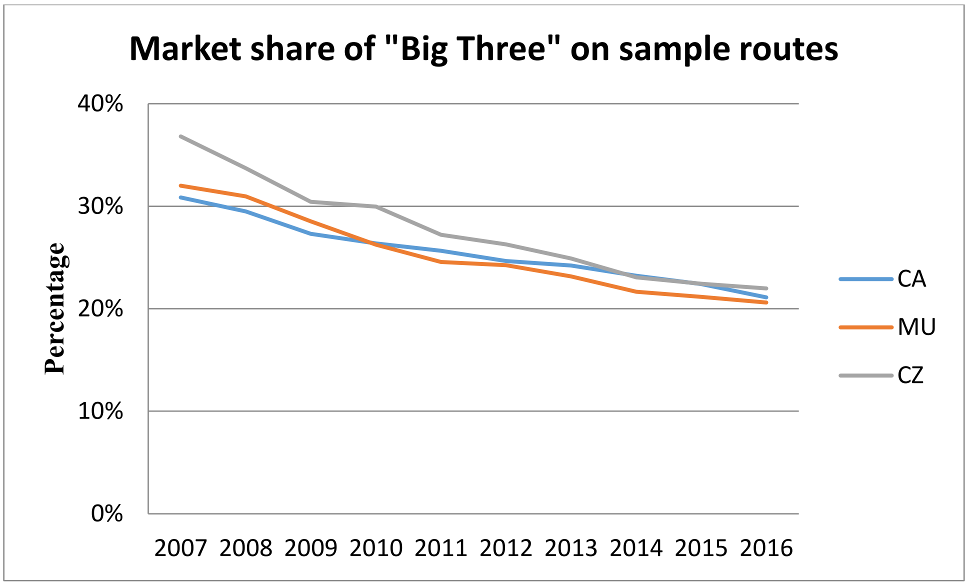

Fig. 2 Market share of “Big Three” on sample routes

Fig. 3 shows that the average price dispersion on the routes over 850 km is higher than that on the routes shorter than 850 km. It also shows that the average price dispersion trended upward over time for both route categories. When there was a presence of HSR, Fig. 4 illustrates that on the routes shorter than 850 km, the average price dispersion was much lower than that on the longer routes, particularly after 2014.

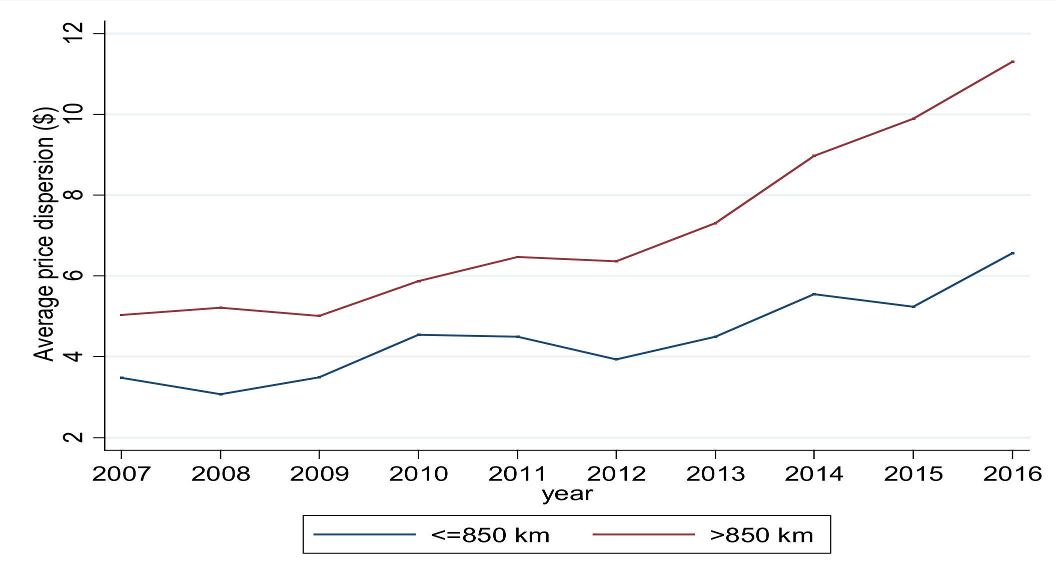

Fig. 3 Average price dispersion on short- and long-haul routes

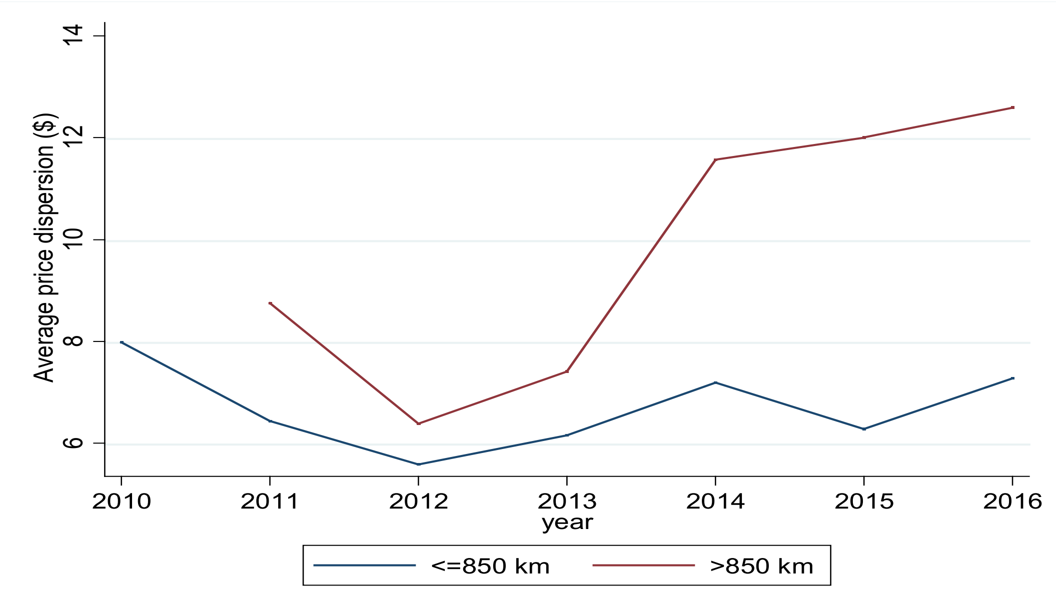

Fig. 4 Average price dispersion on short- and long- haul routes with HSR competition

3.2 Measuring price dispersion

There are three common indicators used to measure price dispersion in the existing literature — the Gini coefficient, Atkinson index, and Entropy index (Hayes and Ross, 1998; Mantin and Koo, 2009). Among them, the most accepted indicator is the Gini coefficient (Borenstein and Rose, 1994; Gerardi and Shapiro, 2009; Orlov, 2011). Gini coefficient is defined as twice the expected absolute difference between two ticket prices drawn randomly from the population.

These measures are effective indicators quantifying price dispersion among passengers who bought the same flight product, and thus are good proxies for intra-firm price dispersion. Although Juhn et al. (1993) proposed a standard approach to calculate interfirm price dispersion, it has to be computed based on the intra-firm GINI coefficient. In addition, we do not have individual purchase information. The airfare data used in this paper are monthly average which does not allow us to construct intra-firm price dispersion measures. We thus use two other indicators for price dispersion in this paper. The price dispersion in this paper measures the average interfirm price variation on a monthly basis.

The first indicator is the coefficient of variation, which is defined as the standard deviations of the pair-wise average fare divided by the mean of the pair-wise fare. It is used to investigate how the variance of prices across pairs of firms changes over time within a market. Borenstein and Rose (1994) found that the results by using the coefficient of variation and the GINI coefficient are quite consistent. The second indicator for price dispersion is called "price difference", which is proposed by Ciliberto et al. (2019) based on the theoretical work by Werden and Froeb (1994). It is defined as the price difference between an airline pair on the same route at a specific time.

Two way ANOVA and t-pair tests will be conducted to provide an overview of the trend that airline-pair fare coefficient variation experienced before and after HSR entry. The results of coefficient of variation will be shown in the first part of Section 4. However, without controlling for other factors that affect airline pricing, it is impossible to quantify the pure impact of HSR on airline-pair price dispersion. Therefore, an econometric model will be developed to regress the second indicator "price difference". We introduce the model and relevant economic issues in the following subsection 3.3 and present the regression results in the second part of Section 4.

3.3 Econometric model

Following Evans and Kessides (1994), Ciliberto and Williams (2014) and Ciliberto et al. (2019), we adopt a reduced-form fare equation to estimate price dispersion. The model is constructed as follows.

$$\ln(FareDiff)_{hk,mt} = \gamma_0 + \gamma_1 HSR_{mt} + \gamma_2 \ln(CostDiff)_{hk,mt} + \gamma_3 X_{mt} + v_{hk,j} + \sigma_t + u_{hk,mt} \quad (1)$$

The dependent variable is the logarithm form of price difference between airline h and airline k in market m at time t. As our study period spans 10 years, airfares have been adjusted using

CPI. The key independent variable of interest is HSR. It is a market-level dummy that takes the value of one if direct HSR service is available on route m at time t. We constructed the variable by manually gathering specific HSR schedule data from the *National Railway Passenger Train Timetable* (2010-2016). It corresponds to the specific entry time of each route. In China, the HSR speeds vary on different routes. Therefore, apart from the HSR dummy we also use the interaction term of HSR and HSR travel time to capture the impact of HSR.

Other control variables following previous literature such as Borenstein (1985) and Holmes (1989) are summarized below.

- lnCostdiff: a cost variable which is the log value of route level marginal cost difference (absolute value) between an airline pair. The route level marginal cost is calculated based on the method proposed in Brander and Zhang (1990, 1993) and detailed in Zhang (2015).
- lnLernerdiff: a market power variable which is the log value of the difference of the route level Lerner indices (absolute value) between an airline pair. Lerner index is calculated using the formula $Lerner = (airfare - marginal\ cost)/airfare$, which is highly correlated with lnCostdiff (with the correlation coefficient being 0.63). Therefore, in regression analysis, lnLernerdiff and lnCostdiff are not included in the same model specification.
- lnHHI: the market-level HHI in logarithmic form measuring market concentration. It is computed based on monthly passenger volume carried by each airline on a route. Besides HHI, we also use the number of carriers, and market structure indicators such as monopoly\duopoly\competitive dummies to conduct robustness checks (Zhang and Round, 2012). Monopoly refers to a route on which an airline has a market share of more than 80%. Duopoly refers to the route in which two airlines share a market share of more than 80%. The competitive dummy captures other cases.
- Market density variables: According to Ma et al. (2020), tacit collusion is most likely to happen on densely travelled routes in China's airline market. We thus categorise the routes into four groups based on the revenue generated: the top 25% of the routes, the second quartile (26-50%), the third quartile (51%-75%) and the fourth quartile (76%-100%). They are denoted by category dummies Rev25, Rev50, Rev75, and Rev100, respectively.
- lnFlight: another market density variable, which is the logarithmic value of the arithmetic mean of the numbers of scheduled flights operated at the two endpoints.
- LCC, a dummy denoting the presence of Chinese LCC—Spring Airlines, Jiuyuan

Airlines, West Airlines, and Lucky Air. Most LCCs have cancelled services in the markets with parallel HSR, suggesting that HSR is a close substitute of the LCC product (Wu et al., 2020).

- $\nu_{hk,j}$ is the carrier-pair-route level unobservable fixed effect.
- σ_t is the time-specific fixed effects, i.e. year and quarter dummies.
- $u_{hk,mt}$ is the error term.

Before estimating the empirical model, there are several econometric issues have to be clarified. First, we assume that the location and entry time of HSR are exogenous to airline pricing decisions. Chinese Railway Cooperation and Civil Aviation Administration of China are two separate departments with little coordination. That is, HSR's construction is fairly irrelevant to airline networking. Etro (2008) shows that when an entry is independent of the profitability conditions, the entry is exogenous and the market leaders may adopt accommodating strategies or aggressive strategies. However, in markets where entry is endogenous, the market leader always adopts aggressive strategies to exclude rivals. After HSR was introduced, airlines have gradually adjusted their airfares and flight schedules in response to HSR competition, but there is no way to exclude HSR. Therefore, assuming HSR's entry is an exogenous decision is reasonable. Similarly, the LCC entry is also considered exogenous. Zhang and Lu (2013) and Wang et al. (2018) find that China's LCCs have the effect of reducing the airfares and promoting the demand for air travel, but they are not game changers as China's aviation policy is overly protective of the state-owned airlines, and the LCCs do have access to most of the profitable markets (Zhang and Zhang, 2017; Yu et al., 2019; Wu et al., 2020).

Another issue is the endogeneity problem associated with HHI. To cope with this issue, some papers use route distance as an instrument (Borenstein and Rose, 1994). Gerardi and Shapiro (2009) later pointed out that route distance is a weak instrument since it could be correlated to the airfare. Kwoka and Shumilkina (2010) show that any possible endogeneity associated with the concentration variable does not greatly affect their results. Gayle and Wu (2013) demonstrate a similar result. Brueckner et al. (2013) also argue that bias from the potential endogeneity of the competition variables is not a major concern. Following Zhang and Round (2011) and Gerardi and Shapiro (2009), we use the geometric mean of the population and the geometric mean of income at two endpoints of a market as instruments. *F* tests show that they are strong instruments. However, in some cases, the Sargan tests show that the instruments are not strictly exogenous. In fact, finding good instruments is always a difficult task, especially when a large number of fixed effects are involved in the model (Orlov, 2011). Therefore, we do not report the instrumental results and try to discuss the results of market structure variable with caution and avoid explaining the results as causal effects. Besides, we also use other proxy variables such as "number of carriers on a route" and market structure dummies to re-test the results of "HHI". The magnitudes and significance remain largely consistent and robust.

To control for the airline-, route-, and time-specific unobservables, we include two sets of fixed effects: airline-pair-route fixed effects and time fixed effects. The airline pair-route fixed effects capture airline-route specific price factors that remain constant over time. These fixed effects also account for other temporally constant factors related to an airline's dominance in origin or destination airports. Time fixed effects capture changes in time-specific variables. As with Goolsbee and Syverson (2005), we cluster our standard errors by route, to control for both serial correlation and correlation between the pricing decisions of different carriers on the same route.

4. Results

In this section, we first present the comparison results of the coefficients of variation. We then present the regression results with price difference being the dependent variable.

4.1 Coefficient of variation

As a good substitute for air, the entry of HSR is expected to increase competition when an origin and destination market definition includes both HSR and air transport. Previous literature has well documented that the air-HSR substitutability varies largely upon route distance (Wan et al., 2016; Wang et al., 2018). Following Wang et al. (2018), we group the routes into two categories: shorter than 850 km and longer than 850 km. To get a preliminary picture of the change in price dispersion after the HSR entry, a two-way ANOVA was conducted on a sample of 24,534 observations to examine the effects of route distance and HSR entry on the coefficient of variation. The two-way ANOVA compares the mean differences between groups that have been split on two independent variables. In this paper, two independent variables are distance and HSR entry, respectively. Distance is a dummy variable, which is equal to 1 if a route is shorter than 850 km. HSR entry is a dummy variable, taking the value of 1 after the HSR entry and 0 otherwise. Table 1 shows that there was a significant effect between the interaction of route distance and HSR entry on the coefficient of variation ($F(1, 24514) = 442.78$, $p = .0000$).

Table 1 Two-way ANOVA Test

Source	Partial SS	Df	MS	F	Prob > F
Model	43,095,677.5	3	14,365,225.8	1,425.8	0.0000
Distance	28,633,111.7	1	28,633,111.7	2,841.9	0.0000

HSR entry	5,497,053.5	1	5,497,053.5	545.6	0.0000
Distance*HSR entry	4,461,098.3	1	4,461,098.2	442.8	0.0000
Residual	246,983,540.0	24,514	10,075.2		

Since Table 1 presents a statistically significant interaction, it is worth exploring the simple main effects. In our paper, this would involve determining the mean difference in the coefficient of variation between HSR entry at each distance level. The paired t-test is applied to investigate simple main effects. The results are shown in Tables 2 and 3.

Table 2 Two-sample t-test with equal variances (Group 0: HSR=0; Group 1: HSR=1)

Group	**Obs**	**Mean**	**Std.Err.**	**Std.Dev.**	**[95% Conf.**	**Interval]**
0	15,856	172.2	0.8	102.8	170.6	173.8
1	8,662	189.6	1.3	118.2	187.2	192.1
Combined	24,518	178.3	0.7	108.8	177.0	179.7
diff		-17.5	1.4		-20.3	-14.6
		diff = mean(0) - mean		**t = -12.1**		
	Ho: diff = 0		**degrees of freedom = 24516**			
	Ha: diff < 0		**Ha: diff != 0**		**Ha: diff > 0**	
	Pr(T < t) = 0.0000		**Pr(|T| > |t|) = 0.0000**		**Pr(T > t) = 1.0000**	

Table 3 Two-sample t-test with equal variances (Group 0: HSR*Short=0; Group 1: HSR*Short=1)

Group	**Obs**	**Mean**	**Std.Err.**	**Std.Dev.**	**[95% Conf.**	**Interval]**
0	21,989	181.0	0.7	107.1	179.6	182.4
1	2,529	155.4	2.4	119.7	150.7	160.1
Combined	24,518	178.3	0.7	108.8	177.0	179.7
diff		25.6	2.3		21.1	30.1
		diff = mean(0) - mean		**t = 11.2**		
	Ho: diff = 0		**degrees of freedom = 24516**			
	Ha: diff < 0		**Ha: diff != 0**		**Ha: diff > 0**	
	Pr(T < t) = 1.0000		**Pr(|T| > |t|) = 0.0000**		**Pr(T > t) = 0.0000**	

The results in Table 2 show that overall the coefficient of variation became larger after the HSR entry. That is, the pricing variation of the airline-pair on a route fluctuated in a larger range than before. Table 3 reports the comparison of the coefficients of variation on the short-haul routes (below 850 km) and the long-haul routes (over 850 km) where HSR was present. It can be seen that after the HSR entry, the airline-pair pricing variation was significantly smaller on the short-haul routes than long-haul routes. Competition is normally stronger as there are more substitutes. These results seem to indicate that competition is negatively associated with price dispersion on the short-haul routes. In the next subsection, regression results on "price difference" are given to further check HSR's role on airfare dispersion.

4.2 Regression results on "price difference"

The regression results are reported in Table 4. As lnLernerdiff is highly correlated with lnCostdiff, they are regressed in separated model specifications. Columns (1) and (3) present results with cost variable while Columns (2) and (4) present results with Lerner index variable. As can be seen, the coefficients of the key explanatory variable "HSR" are positive and significant, which is in line with the t-test results in Table 2. This means that holding other variables constant, the price difference among the "Big Three" increased by approximately 22% [3] on the route where HSR was present. The result is contrary to the view that price dispersion decreases with higher competition. Column (3) replaces "HSR" with an interaction term "HSR*Traveltime" as a robustness check. The result shows that as the travel time with HSR becomes longer, the positive effect of HSR on the price dispersion of "Big Three" is more pronounced.

Table 4 Basic regression results for Model (1)

	(1)	(2)	(3)	(4)
HSR	0.2013***	0.1705***		
	(0.0167)	(0.0161)		
HSR*Traveltime			0.1246***	0.1097***
			(0.0121)	(0.0117)
lnCostdiff	0.0146***		0.0154***	
	(0.0038)		(0.0038)	
lnLernerdiff		0.1974***		0.1979***
		(0.0033)		(0.0033)
lnHHI	0.2677***	0.2388***	0.2837***	0.2516***
	(0.0215)	(0.0207)	(0.0214)	(0.0206)
LCC	0.0573**	0.0330	0.0510**	0.0274
	(0.0235)	(0.0227)	(0.0235)	(0.0227)
lnFlight	-0.0356***	-0.0595***	-0.0372***	-0.0607***
	(0.0116)	(0.0112)	(0.0116)	(0.0112)
Rev25	-0.1727***	-0.0908***	-0.1781***	-0.0950***
	(0.0220)	(0.0213)	(0.0220)	(0.0213)
Rev50	-0.1929***	-0.1282***	-0.1975***	-0.1319***
	(0.0177)	(0.0171)	(0.0177)	(0.0171)
Rev75	-0.1083***	-0.0721***	-0.1096***	-0.0731***
	(0.0141)	(0.0136)	(0.0141)	(0.0136)
Constant	0.1061	0.9941***	0.0180	0.9264***
	(0.1843)	(0.1780)	(0.1840)	(0.1778)
R^2	0.140	0.142	0.140	0.142
N	50,128	50,128	50,128	50,128

1. Clustered standard errors in parentheses.
2. $^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.

All the market density variables including lnFlight, Rev25, Rev50, and Rev75, are negative and significant, meaning that the more flights are on the route and higher revenue generated, the smaller the price differences in prices between the "Big Three". Ma et al. (2020) found

[3] The percentage is calculated as $e^{-0.2013} - 1$.

that Chinese airlines are most likely to engage in collusive behaviour on densely travelled routes. The smaller price dispersions on densely travelled markets are likely to be a sign of price-fixing as the "Big Three" have a strong incentive to maintain the prices on the profitable routes. Zhang and Round (2011) and Zhang (2015) have also documented these anti-trust practices in China's airline industry.

The cost variable is a critical factor related to airline pricing behaviour. The coefficient of lnCostdiff is significant and negative, indicating that the cost difference is an important factor influencing price dispersion among the "Big Three". However, the magnitude of lnCostdiff is rather small compared to market structure variables, meaning that cost difference is not the key factor affecting the price dispersion among the "Big Three".

The coefficient of lnLernerdiff in Columns (2) of Table 4 shows that the difference in market power measured by the Lerner index is a significant factor causing greater price dispersion. If the difference in the Lerner index increases by 1%, the price dispersion among the "Big Three" would increase by 19.74%. This implies that if an airline dominates the market and processes significant market power while other airlines in the same market have little market power, price dispersion is likely to be greater.

The coefficients of LCC is significantly positive in Columns (1) and (3), and insignificant in Columns (2) and (4). The positive impact may imply that one of the "Big Three" would respond to LCC pricing by offering lower prices while the other would not match the LCC prices, thereby resulting in a larger price dispersion.

Lastly, the coefficients of lnHHI in all the model specifications are significantly positive, indicating that the higher the concentration, the greater the price dispersion. The price discrimination theory suggests that high market power can lead to more diverse prices for the same product. It seems that a higher ability in price discrimination can also result in a higher interfirm price dispersion in our case. As HHI could raise endogeneity concerns, Table 5 uses several methods to address this issue. Columns (1) and (2) in Table 5 use the geometric mean of the population and the geometric mean of GDP as the instrumental variables. Columns (3) and (4) use the one-period lag value of HHI instead of current value to deal with the endogeneity issue. Higher-degree lagged values of HHI are also tried, and our results do not change much. We also replace HHI with the number of carriers in Columns (5) and (6) to provide a robustness check for HHI. The results of the variable "lnNoCarrier" shows that price dispersion is negatively associated with the number of carriers on a specific route. This indicates that an increase in competition leads to a decrease in interfirm price dispersion in

China's airline market, which is consistent with the monopoly effect view, that in highly competitive markets different sellers are expected to ask the same price for a certain product (Baffes, 1991).

Table 5 Regression results when HHI is treated as endogenous

	(1)	(2)	(3)	(4)	(5)	(6)
HSR	0.1873***	0.1356***	0.2230***	0.1900***	0.1998***	0.1657***
	(0.0233)	(0.0224)	(12.70)	(11.17)	(0.0168)	(0.0163)
lnCostdiff	0.0145***		0.0169***		0.0157***	
	(0.0038)		(4.20)		(0.0038)	
lnLernerdiff		0.1962***		0.1960***		0.1984***
		(0.0033)		(56.04)		(0.0033)
lnHHI	0.3943***	0.5560***				
	(0.1485)	(0.1433)				
L.lnHHI			0.2010***	0.1900***		
			(8.74)	(8.56)		
lnNoCarrier					-0.2212***	-0.2208***
					(0.0239)	(0.0231)
LCC	0.0671**	0.0576**	0.0385	0.0116	0.0708***	0.0486**
	(0.0261)	(0.0253)	(1.55)	(0.48)	(0.0238)	(0.0229)
lnFlight	-0.0312**	-0.0482***	-0.0304*	-0.0611***	-0.0379***	-0.0609***
	(0.0127)	(0.0123)	(-2.18)	(-4.52)	(0.0116)	(0.0112)
Rev25	-0.1869***	-0.1269***	-0.1570***	-0.0768***	-0.1590***	-0.0800***
	(0.0275)	(0.0267)	(-6.67)	(-3.38)	(0.0220)	(0.0212)
Rev50	-0.1974***	-0.1400***	-0.1850***	-0.1200***	-0.1958***	-0.1319***
	(0.0184)	(0.0179)	(-9.75)	(-6.55)	(0.0177)	(0.0171)
Rev75	-0.1076***	-0.0706***	-0.1020***	-0.0657***	-0.1166***	-0.0800***
	(0.0141)	(0.0137)	(-6.75)	(-4.48)	(0.0141)	(0.0137)
Constant			0.6190**	1.4060***	2.6219***	3.2831***
			(3.12)	(7.34)	(0.0746)	(0.0718)
R^2	0.137	0.138	0.141	0.146	0.143	0.142
Sargan Statistics	6.512	21.503				
P-value	0.0107	0.0000				
F Statistics	147.10	286.33				
N	50,106	50,106	44,478	44,478	50,128	50,128

1. Clustered standard errors in parentheses.
2. . * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In sum, it is clear that most of the competition and concentration variables point to the conclusion that the higher concentration generates greater interfirm price dispersion and that increased competition reduces price dispersion in China's airline market. However, our results also show that the presence of HSR enlarges price dispersion. This counters intuitive if HSR adds competition in an original and destination market. A possible explanation is that HSR facilities collusion among Chinese airlines. In fact, Ma et al. (2019) examined the air-HSR competition in the Beijing-Shanghai market and found that price coordination is more likely to happen in the presence of HSR. This is similar to the finding in Ciliberto et al. (2019) that as a substitute for full-service airlines (FSAs), LCCs can facilitate tacit collusion among FSAs in the US aviation market. Ma et al. (2019) thus warned that antitrust authorities should stay vigilant in monitoring the Beijing-Shanghai market given that it is the busiest airline route and the most profitable route for all airlines involved. When airlines act as one firm, they can manage prices, which may lead to planned price dispersion.

Wang et al. (2018) found that the HSR effect varies with the intermodal substitutability and the threshold of air-HSR substitutability is 850 km. Tables 1 and 3 show that the impact of HSR on price dispersion could be different across markets with different distances. Therefore, in Table 6, we further analyse the impact of HSR on the price dispersion on the short-haul and long-haul routes, respectively.

Table 6 Impacts of HSR on price dispersion in different distance groups

	(1)	(2)	(3)	(4)
HSR*D1	-0.0701**		-0.0983***	
	(0.0282)		(0.0272)	
HSR*D2		0.2623***		0.2378***
		(0.0179)		(0.0173)
lnCostdiff	0.0151***	0.0161***		
	(0.0038)	(0.0038)		
lnLernerdiff	0.0151***	0.0161***	0.1988***	0.1976***
	(0.0038)	(0.0038)	(0.0033)	(0.0033)
lnHHI	0.3076***	0.2676***	0.2741***	0.2366***
	(0.0213)	(0.0214)	(0.0206)	(0.0206)
LCC	0.0503**	0.0431*	0.0246	0.0203
	(0.0236)	(0.0235)	(0.0228)	(0.0227)
lnFlight	-0.0422***	-0.0345***	-0.0653***	-0.0581***
	(0.0116)	(0.0116)	(0.0112)	(0.0112)
Rev25	-0.1856***	-0.1734***	-0.1018***	-0.0907***
	(0.0220)	(0.0220)	(0.0213)	(0.0213)
Rev50	-0.2031***	-0.1957***	-0.1372***	-0.1303***
	(0.0177)	(0.0176)	(0.0171)	(0.0171)
Rev75	-0.1093***	-0.1074***	-0.0726***	-0.0711***
	(0.0141)	(0.0141)	(0.0136)	(0.0136)
Constant	-0.0602	0.1036	0.8540***	1.0062***
	(0.1842)	(0.1840)	(0.1779)	(0.1778)
R^2	0.140	0.139	0.141	0.144
N	50,128	50,128	50,128	50,128

1. Clustered standard errors in parentheses.
2. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

In Table 6, the dummy D1 indicates that the route distance is less than 850 km while D2 indicates that the route distance is longer than 850 km. It can be seen from Table 6 that price dispersion among the “Big Three” decreases when HSR entered markets shorter than 850 km. On the routes longer than 850 km, the dispersion of the “Big Three” increases significantly after the HSR entry. These results may suggest on the short-haul routes, HSR is a good substitute and a strong competitor to airlines. The increased competition results in a reduction in price dispersion. However, on the long-haul routes, it seems that HSR’s attractiveness diminishes, and the airfares distribute in a larger range. The entry of HSR may have forced the airlines to act together to restrict capacity and manage prices. For example, by working together, airlines can charge higher prices to price-insensitive passengers and allow lower prices to be offered to keep some price-sensitive passengers from switching to HSR. The results of other variables are highly consistent with Table 5. We also used the instruments for HHI and the results remain consistent.

It can be seen from Tables 4-6 that market concentration is the most important factor affecting the price dispersion of the "Big Three". We now examine the effect of HSR on price dispersion in the highly concentrated markets. We focus on the duopoly markets where two of the "Big Three" command a market share of over 80%. The interaction terms of HSR and HHI, and HSR and the dummy "Duopoly" are included in the model. The results are reported in Table 7, which suggest that on the routes with HSR, the higher the route concentration, the greater the price dispersion. In the duopoly markets, HSR is also associated with higher price dispersion. The results of other variables are highly consistent with the previous tables.

Table 7 Impacts of HSR on price dispersion in highly concentrated markets

	(1)	(2)	(3)	(4)
HSR*lnHHI	0.0292***	0.0249***		
	(0.0020)	(0.0020)		
HSR*Duopoly			0.8182***	0.7592***
			(0.0556)	(0.0536)
lnCostdiff	0.0148***		0.0166***	
	(0.0038)		(0.0038)	
lnLernerdiff		0.1983***		0.1990***
		(0.0033)		(0.0033)
LCC	0.0368	0.0146	0.0365	0.0147
	(0.0235)	(0.0227)	(0.0235)	(0.0227)
lnFlight	-0.0445***	-0.0675***	-0.0494***	-0.0713***
	(0.0116)	(0.0112)	(0.0116)	(0.0112)
Rev25	-0.1426***	-0.0637***	-0.1527***	-0.0721***
	(0.0219)	(0.0212)	(0.0219)	(0.0212)
Rev50	-0.1829***	-0.1191***	-0.1898***	-0.1245***
	(0.0177)	(0.0171)	(0.0177)	(0.0171)
Rev75	-0.1094***	-0.0729***	-0.1121***	-0.0751***
	(0.0141)	(0.0137)	(0.0141)	(0.0136)
Constant	2.2581***	2.9172***	2.3750***	3.0207***
	(0.0637)	(0.0611)	(0.0627)	(0.0599)
R^2	0.139	0.140	0.140	0.141
N	50,128	50,128	50,128	50,128

1. Clustered standard errors in parentheses.
2. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5. Conclusions

While the studies of the effect of HSR on airline prices are large in number, research on the impact of HSR price distribution is still relatively rare. This paper has studied the price dispersion among China's "Big Three", namely, Air China, China Eastern, and China Southern.

Our results consistently suggest that HSR in China has a positive link with the airline price dispersion except on the short-haul routes where HSR is highly substitutable for air transport and thus the HSR competition effect dominates, resulting in smaller price dispersion. On the long haul routes, HSR is less substitutable, and its role in enhancing competition is limited. There is a possibility that the presence of HSR actually facilitates airline cooperation in setting prices and outputs, thereby leading to greater price dispersion. All the market structure and competition variables included in this study support the conclusion that price dispersion is greater in more concentrated and more densely travelled markets.

These findings have significant anti-trust implications. Historically, price collusion was common in China's aviation market and price-fixing activities were actually encouraged by the aviation authorities, particularly on the trunk routes (Zhang, 2011; Zhang and Round, 2011). Tacit collusion, particularly unconscious collusive arrangement, may not be necessarily banned by China's current Anti-Monopoly Law, but such behaviour can cause increases in prices and cuts in capacity, which result in a loss in consumer welfare. The general public should have the right to demand an anti-trust investigation into the airline pricing behaviour in the presence of HSR. In addition, any types of collusive conducts and the associated gains may incentivize the incumbents to create higher entry barriers for the LCCs that are less likely to engage in price collusion or abide by a collusive agreement. This will hinder the network development of Chinese LCCs.

The findings of this paper contribute to the debate on the relationship between competition and price dispersion, particularly the interfirm price dispersion. We have provided further evidence supporting the traditional microeconomic theory that competition reduces price dispersion. However, as we use the monthly average data in this research, we may not disclose the whole picture of the price dispersion patterns in China's aviation market, which is a limitation of this study. Ideally, future studies can use flight-level data to examine both intra- and interfirm price dispersion.

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Appendix: List of airlines included in the sample

IATA Code	Airline Name	IATA Code	Airline Name
HU	Hainan Airlines	KY	Kunming Airlines
3U	Sichuan Airlines	OQ	Chongqing Airlines
CZ	China Southern Airlines	9C	Spring Airlines
FM	Shanghai Airlines	JR	Joyair
CA	Air China	TV	Tibet Airlines
MF	Xiamen Airlines	KN	China United Airlines
HO	Juneyao Airlines	GJ	Loong Air
MU	China Eastern Airlines	DZ	Donghai Airlines
EU	Chengdu Airlines	DR	Ruili Airlines
ZH	Shenzhen Airlines	QW	Qingdao Airlines
SC	Shandong Airlines	YI	Ying'an Airlines
8C	East Star Airlines	UQ	Urumqi Airlines
8L	Lucky Air	FU	Fuzhou Airlines
BK	Okay Air	GX	Beibu Gulf Airlines
G5	China Express Airlines	AQ	9 Air
PN	West Air	GY	Colorful Guizhou Airlines
GS	Tianjin Airlines	Y8	Suparna Airlines
CN	Grand China Air	RY	Jiangxi Airlines
NS	Hebei Airlines	9H	Air Chang'an
VD	Kun Peng Airlines	A6	Air Travel
JD	Capital Airlines	GT	Air Guilin