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# The implications of high-speed railways on air passenger flows in China

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ABSTRACT

The High-speed Railway (HSR) network in China is the largest in the world, competing intensively with airlines for inter-city travel. Panel data from 2007 to 2013 for 138 routes with HSR-air competition were used to identify the ex-post impacts of the entry of HSR services, the duration of operating HSR services since entry, and the specific impacts of HSR transportation variables such as travel time, frequency, and ticket fares on air passenger flows in China. The findings show that the entry of new HSR services in general leads to a 27% reduction in air travel demand. After two years of operating HSR services, however, the negative impact of HSR services on air passenger flows tends to further increase. The variations of the frequency in the temporal dimension and the travel time in the spatial dimension significantly affect air passenger flows. Neither in the temporal nor spatial dimensions are HSR fares strongly related to air passenger flows in China, due to the government regulation of HSR ticket prices during the period of analysis. The impacts of different transportation variables found in this paper are valuable to consider by operational HSR companies in terms of scheduling and planning of new routes to increase their competitiveness relative to airlines.

## 1. Introduction

Efficiently operated High-speed railways (HSRs) offer advantages in punctual departure/arrival time, comfortable travel experience, and less CO2 emission in comparison to air travel (Givoni, 2007; Hall, 2009). The first HSR corridor was inaugurated in Japan in 1964. Then the first European HSR, TGV Sud-Est, between Paris and Lyon was opened in 1981 in France. Thereafter, many HSR lines have been constructed in other Western European countries, including ICE in Germany and AGV in Spain (Givoni, 2006). Although inaugurated in a later stage, Chinese HSR networks have expanded at an exponential growth rate because of a substantial financial support from the central government. Especially after 2008, a 4 trillion RMB stimulus package to mitigate the impact of the global financial crisis has more than doubled the investment capital for HSR construction (Amos, Bullock, & Sondhi, 2010). From the end of 2003, when the first HSR between Shenyang and Qinhuangdao was opened, until 2015, the Chinese HSR networks increased to 19,000 km, accounting for more than 60% of global HSR networks. Chinese HSR networks were constructed in only 12 years, and on a scale larger than in the rest of the world. Regarding the fast development of HSR networks in China, a large volume of literature has reported the impacts of HSR services on local and regional economy (Chen & Haynes, 2017; Ke, Chen, Hong, & Hsiao, 2017), urban specialization pattern (Lin, 2016) and urban service industry agglomeration (Shuai, Tian, & Yang, 2017). However, the focus on the interaction between HSR and air travel is still limited in the context of China.

Different from the European HSR networks, which were developed in a relative mature aviation market with modest growth rates, the development of Chinese HSR networks parallels a fast-growing and partially deregulated aviation market (Wang et al., 2016). After two decades of air deregulation in China, China's air transportation has experienced rapid growth, especially from the start of the economic reform in 1980s due to the rapid increase in air travel demand (Wang et al., 2016). Between 1997 and 2015, domestic air passenger traffic in China grew from 5.6 million passengers to 436 million. The annual airline growth rate was almost 10%, particularly after 2000. However, the annual growth rate of air travel is prone to be affected by unexpected social events, such as the 2003 outbreak of Severe Acute Respiratory Syndrome (SARS) and the 2008 financial crisis. In addition, after HSR operations started, first the D train services with an average operational speed 200 km/h in 2007 and then G train services with an average operational speed of 300 km/h in 2009, the airline's annual

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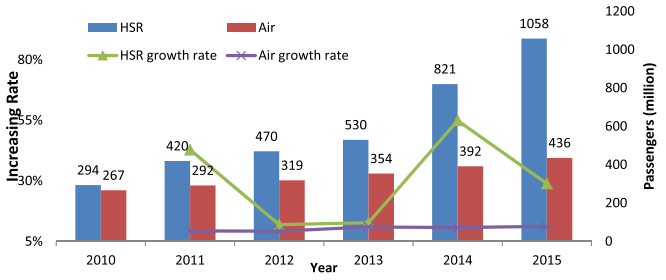


**Fig. 1.** Annual volume of national air and HSR traffic from 2010 to 2015 (CAAC).

growth began to drop progressively to reach stable growth after 2012 when there were remaining regulation, limited investment, and poor overall national policy on the aviation industry. Fig. 1 shows that China's aviation market has been in a stage of fast growth in parallel to the expansion of HSR networks. While the volume of both air and HSR traffic increased between 2010 and 2015, HSR did so at a higher growth rate. This reflects the potential competition that HSR services offer for passenger transportation in China. Apart from unexpected socio-economic events, the operation of HSR services has absorbed the demand growth for airline travel to a certain extent. In addition, HSR network expansion triggered loosening of regulations on airlines by the Civil Aviation Administration of China (CAAC), such as partially flexibile air fares and more operator licenses for private and low cost airline companies (Zhang, Yang, Wang, & Zhang, 2014).

Ex-ante studies of HSR and aviation demand have been conducted intensively, primarily predicting the intermodal market share and focusing on a handful of major corridors where HSR development has occurred (Gonzalez-Savignat, 2004; Mao, 2010; Park & Ha, 2006; Román, Espino, & Martín, 2007). In contrast, very often a lot of ex-post studies such as reports, white papers conducted or commissioned by transportation companies are unavailable to the public due to due to the confidentiality of the operational data from the transportation companies (Dobruszkes, Dehon, & Givoni, 2014; Li & Loo, 2016). Ex-post research is further relatively limited in academia, especially in China with a strong governmental control on the railway and aviation industry and the application of relevant HSR geo-economic and transportation variables is rather crude in the data and model application.

This paper aims to fill this gap by conducting an ex-post study on the impact of HSR on air travel demand in the context of China using balanced and unbalanced panel data analysis. Firstly, using a balanced panel data set collected for 270 cross-sections over seven years, we examine the relationship between HSR services and air passenger demand using variance component models. The analysis takes into account city pairs with and without HSR-air competition over the period 2007–2013 to understand the impact of geo-economic HSR variables (such as HSR entry and duration of operating HSR services) on air travel demand. Secondly, we employ within-between models (Bell & Jones, 2015; Nieuwenhuis, Hooimeijer, van Ham, & Meeus, 2016), using an unbalanced dataset containing only 138 city pairs with HSR-air competition from 2007 to 2013, to specify how HSR transportation variables are specifically interacted with the air travel demand in the two geographic (temporal and spatial) dimensions. We do so because the transportation variables, such as frequency, travel time, and fare, vary both in terms of the duration of operation of the HSR services (temporal dimension) and between different HSR routes (spatial dimension). Previous research has focused mainly on one of the dimensions.

In the next section, we present a literature review on the competition between HSR and air transportation. Following this is the research design, which discusses the variables used and data collection, as well as methodologies for the panel data analysis. The subsequent sections present the empirical results of the balanced and unbalanced panel data analysis. Finally, we discuss our main findings and their policy implications.

## 2. Literature review

Although there is cooperation between airlines and HSRs by means of feeding passengers from HSR spokes to hub airports (if booking systems between airlines and HSR companies have been coordinated) (Givoni & Banister, 2006), HSR has substantial competitive effects on air transportation, especially on point-to-point city pair markets. Research has confirmed that after the opening of new HSR services, the HSR will have substitution effects on air travel by means of diverting original air passenger flows into the HSR. The first study is from Janić (1993), who claimed that HSR transportation in Europe competes with air transportation over a relatively large range of distances, between 400 and 2000 km. A broad range of ex-ante academic literature then emerged, focusing on the impacts of HSR on predicted demand for airline travel in different contexts. In France, Haynes (1997) found that after a few years of HSR operation, air traffic dropped by 50% between Paris and Lyon. In Spain, González-Savignat (2004), based on a stated preference experimental design, predicted the HSR's impacts on the reduced market share of airlines (50%) between Madrid and Barcelona. In Korea, Park and Ha (2006), relying on the stated preference model calibration, examined the effects of HSR on domestic air transportation demand in Korea and estimated a demand reduction between 34% and 75% between Seoul and Daegu. In Germany, to describe the consumer selection behavior between HSR and airlines, Ivaldi and Vibes (2005) used a theoretical simulation model to analyze the intermodal competition in the Cologne-Berlin route, finding that the entry of HSR reduces the fares and the airline flight frequency.

With the fast development of HSR, especially in China and Europe, a few ex-post studies of HSR impacts on air travel have been carried out. The advantage of ex-post research is the accuracy of reflecting the actual effect of intermodal competition rather than the relatively poor performance of prediction embedded in ex-ante research (Givoni & Dobruszkes, 2013). Dobruszkes (2011) and Fu, Zhang, and Lei (2012) used aggregated data and observed impacts of HSR-air competition in Europe and China, but did not implement econometric analysis on a large set of routes. That type of observed ex-post research has raised the issues of the unclear causal relationship of HSR-relevant factors and the lack of representativeness. Recently, studies have used econometric analysis to overcome this deficiency by focusing on the cases of Europe and China (Albalate, Bel, & Fageda, 2015; Chen, 2017; Fu, Lei, Wang, & Yan, 2015). However, the indicators for the HSR are dummy variables. These are unable to accurately reflect the influence of HSR related to geographic transportation factors such as travel time, frequency, and ticket fare. Other researchers have used transportation variables of HSR such as travel time, the frequency of trains (Clewlow, Sussman, & Balakrishnan, 2014; Dobruszkes et al., 2014; Zhang, Yang, & Wang, 2017) and the length of railway networks (Li & Loo, 2016) to specify the influence of HSR on airlines using either time series (temporal dimension) or cross-section (spatial dimension) analysis.

Our review of the literature shows that studies regarding the competition between HSR and airlines are largely based on a European context and interpret the transportation variables of HSR only in either the “temporal” or the “spatial” dimension. This means that the variations in transportation variables in the other geographic dimension are not taken into account simultaneously (Table 1). Hence, our first hypothesis is that the influence of the transportation variables varying in the temporal dimension differs from those varying in the spatial dimension. Our panel data set allows for including both dimensions in the analysis. Second, we hypothesize that the entry of HSR services with respect to the growth rate of air travel demand may not be as significant as in Europe until a certain year of operating HSR services. The fast economic growth in Chinese cities and the increasing purchasing power of urban citizens have resulted in a fast-growing potential market for both air travel and HSR travel in China. Although some air passengers