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International trade drivers and freight network analysis - The case of the Chinese air cargo sector

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ABSTRACT

This study identifies the key drivers for China's international trade delivered by air with an augmented gravity model, and investigates the country's air freight network using complex network analysis. Gravity model estimation suggests that income elasticity for airborne trade at country level is 1.1, whereas the values for the three major economic zones are significantly higher. More importantly, we found that for China's international trade by air, the composition of economy is a more important driver than the size of economy. These results suggest that the Chinese air cargo sector will outpace the overall economic growth, with leading airports in the economic zones well-positioned to grow into major freight gateways. Air cargo demand in China was not as high as past GDP numbers suggested in the past, but is likely to experience sustained growth in the years to come. Network analysis suggests that cargo traffic volumes are concentrated in the catchments of metropolitan regions, where passenger hubs also serve as air cargo bases. However, domestic air freights currently mainly flow through a relatively small point-to-point network, suggesting that the leading airports are yet to become cargo gateway hubs despite their significant growth potential.

1. Introduction

For the past three decades, it seems that everything has been on the side of Chinese airlines. From 1978 to 2015, real gross domestic product (GDP) in China grew nearly 10% annually before slowing down to 7% in the last two years. As a result, air passenger traffic grew more than 15% a year during the same period. Chinese airlines enjoy much lower input prices than their international peers (Fu et al., 2012, Wang et al., 2014a); work unions are, in reality, subordinates of airline management; capital costs have been effectively decreasing thanks to currency appreciation till 2014; and there have been continual investments in transport infrastructure, airports, fleets and human resources (Wang et al., 2014b; Fu et al., 2015b). In terms of scheduled traffic, China ranked only seventy-eighth in the world in 1978, but since 2005 the country has become the second largest aviation market, only behind the United States (US). In terms of passenger traffic volume, airlines such as China Southern, China Eastern and Air China have become world leading carriers. Although the market shares of low cost carriers (LCCs) remain low at national level, a few LCCs have achieved rapid growth and have been allowed to serve many densely travelled routes (Fu et al., 2015a). The removal of certain legacy regulations has also promoted market competition and new airline entries (Zhang and Round, 2008).

However, Chinese airlines have not grown their cargo business in the same way as passenger traffic, and they still lag behind established cargo carriers in neighboring economies such as Korean Air, Singapore Airlines, Cathay Pacific and China Airlines. This is remarkable as there are no large integrated carriers competing in the domestic market,[1] whereas the presence of UPS and FedEx partly explains the limited cargo operations of North American commercial airlines. This is rather puzzling, in view of China's leadership in global merchandise trade. Growth of the economy and trade calls for efficient and timely cargo movement, making air freight an indispensable means of logistics in today's global supply chains. Chinese airlines' limited exposure to cargo operations under such favorable circumstances is therefore unexpected, especially considering that many studies have confirmed that cargo operations are likely to improve commercial airlines' productivity, and Chinese airlines have been improving their efficiency continuously

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[1] SF Airlines is a Chinese cargo airline established in 2010 by SF Express, a leading logistics company in China. The airline has been expanding rapidly, but it is size is not comparable to state-owned commercial airlines or international peers such as UPS or FedEx.

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(Hong and Zhang, 2010; Oum and Yu, 1995, 1998; Oum et al., 2005; Homsombat et al., 2010; Wang et al., 2014a). Therefore, this study aims to review the development status of the air cargo sector in mainland China, and empirically investigate the China's air freight drivers and airline network. We use two complementary research components: we first identify the key drivers for international air trade with an augmented gravity model, and then evaluate the air freight network configuration in the Chinese domestic market using complex network analysis. Such an approach allows us to bypass some data restrictions, but nevertheless obtain an overall picture of the industry.

Research on air cargo is less developed compared to what has been achieved in relation to passenger traffic, mainly due to constraints in data availability. Comprehensive data on price and traffic volume at route or airline level are usually not accessible. As demand for transport and logistics services are dependent on other sectors' performances (i.e. transport demands are 'derived' from demands for other commodity and services), some studies chose to estimate gravity models so that the drivers for cargo flow can be identified. This is important in understanding the performance of the air cargo sector since cargo demand and flow pattern determine airlines' operations and network configuration. Gravity models are extensively used in the trade and geography literatures, and studies have been carried out for international air cargo operations. Matsumoto (2004, 2007) adopted a simple gravity model to identify airport hubs for major intra- and inter-continental air traffic. His gravity model controlled for GDP, population, distance and several airport dummy variables. As an extension, Yamaguchi (2008) investigated the effects of transport cost on US air cargo export, although it was based on export data only. Hwang and Shiao (2011) analyzed air cargo flow in Taiwan Taoyuan Airport. More geo-economic variables that might affect international air cargo flow were incorporated into a gravity model, including flight frequency, freight rate, Open Skies Agreement and trading blocs. If the results obtained in these studies were applicable to the air cargo market in China, one would expect faster growth of air cargo operations for Chinese carriers than has been observed. Despite being one of the most important cargo markets in the world, few empirical investigations have been carried out on China's airborne trade. This is probably due to the fact that comprehensive air cargo data are not regularly released to the public. We are fortunate to have access to data on the value of Chinese trade for year 2011 from the General Administration of Customs of China. Although the data only contains a cross-sectional sample for China's top 100 air trade destinations, to our best knowledge it is among the first comprehensive dataset used for the study of the Chinese air cargo sector. Our study provides a good snap shot of the country's aviation and trade performances, which have not been well studied in the literature.

To complement the gravity analysis, we analyze China's aviation network in the corresponding periods. Complex network theory has been developed as a powerful tool for studying the topological features of real-life networks including the Internet and social networks (Albert and Barabasi, 2002). Airport networks can also be analyzed using such an approach (Guimera and Amaral, 2004). Investigations on the aviation network in China found some scale-free features, which suggests the existence of hub airports connecting different airport clusters (Li and Cai, 2004; Zhang et al., 2010a, 2010b; Lin, 2012). Wang et al. (2011) obtained similar network topology and noted that most small and low-degree airports are directly connected to the largest cities bypassing regional centers. Network studies in these articles did not discriminate between passenger and cargo operation. Dang and Peng (2012) conducted a study on the air freight network in China. They found topological features consistent with the afore-mentioned studies, and concluded that there was a significant overlap between passenger and cargo networks. The authors also demonstrated that air freight distribution in China is very imbalanced and airports can be classified into a four-level hierarchical system. Hui et al. (2004) reviewed the Chinese air freight market development in both domestic and international sectors. The authors illustrated that Beijing, Shanghai and Guangzhou are the dominant airports forming a tripod in Chinese domestic air cargo traffic, whereas Hong Kong replaces the role of Guangzhou in international air cargo. Pan et al. (2007), Wei (2011) and Zhang et al. (2010a, 2010b) grouped Chinese airports into various hierarchies by calculating alternative indices. A recent paper by Walcott and Fan (2017) ranked major Chinese airports according to their air cargo network centrality indexes. Beijing and Shanghai are identified as the two national air cargo centers with the highest centrality in the network. Although these studies provided valuable insights into the air cargo industry, they either investigated combined passenger-cargo networks, or focused on hierarchical classification of airports. No study has clearly identified the network pattern of freight networks, e.g. whether the freight network is characterized as a hub-and-spoke network or a point-to-point network. Hub-and-spoke networks are primarily used by integrated carriers such as FedEx and UPS, which distribute a large number of shipments over an extended network. Point-to-point networks have been used by carriers focusing on airport-to-airport carriage, or commercial airlines with limited capacities. Therefore, the network configuration pattern may provide valuable insights into airlines' market development strategies.

To fill these research gaps, this study identifies the key drivers for Chinese international trade delivered by air with an augmented gravity model, and investigates the air freight network in the domestic market using complex network analysis. We hope such an analysis will help understand the air cargo industry development in China by providing a snapshot of the sector's demand status and network configuration, so that some of the key determinants of airline cargo operations can be evaluated. The quantitative investigations carried out also complement qualitative reviews such as that carried out by Zhang (2003) and Zhang et al. (2004) that are the earliest comprehensive discussion on China and Hong Kong air cargo development, the investigation by Fung et al. (2005) on the effects of China's WTO entry in 2001, and Zheng and Chen's (2012) comparison between export and import cargo flows between China and US.

The paper is organized as follows. After a brief overview of the Chinese air cargo industry in recent years, Section 2 investigates the key drivers for international trade delivered by air with an augmented gravity model. Section 3 studies the domestic air freight network using complex network analysis. Summary and conclusions are reported in the last section.

2. Chinese international air cargo flow

Following the commercialization and (partial) deregulation in the early 1980s, the Chinese aviation industry has experienced tremendous growth in both passenger and cargo volumes (Liu and Luk, 2009; Lei and O'Connell, 2011). From 2002 to 2015, air cargo traffic volume in China increased from 4 million tons to 14 million tons at an average annual growth rate of 10.1% (Civil Aviation Administration of China, 2012). Although there were some fluctuations including the sharp declines during the 2008–2009 global financial crisis, most industry players are positive about the long-term prospects. Boeing (2014) predicted that China will continue to lead world air cargo growth for the next two decades, as strong international trade and economic growth will continue to boost air cargo demand. China serves as an important manufacturing base in the global supply chain. Table 1 reports the major trading items of total trade and airborne trade in 2011. Clearly, air freight has facilitated international trade by moving high-value items such as electronics, precision instruments, machinery parts and medicines in a timely manner. The key air cargo destination countries for China are developed countries such as the US, Japan, Hong Kong, and South Korea. This is understandable because China imports production equipment and materials from developed economies. Taiwan and South Korea are key suppliers of electronic boards and LED screens. Japan, the US and Germany provided much of the precision equipment and semi-conductors. This is evidenced in Table 2, which summarizes country pair-wise air cargo shares by value.