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Airport Development and Regional Economic Growth in China

by

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Abstract

Air transport has experienced phenomenal growth in China over the last 30 years, but studies on China's airport development are few. This paper aims to fill in this literature gap by focusing on the determinants of airport development in the Chinese regions using the most up-to-day and comprehensive data on China's airports and their related economic and geographical variables. The empirical results based on an augmented production function indicate that airport development is positively related with economic growth, industrial structure, population density, and openness, but negatively related with ground transportation. The growth of airport transportation in the eastern region is slower than in the inland areas, implying a more significant substitution effect of air transport on ground transport in the less densely populated areas, irrespective of economic activities. The results have useful policy implications as any regional transportation development plan has to simultaneously consider the competitive and supplementary effects of both air and land transports in a specific location.

JEL classification: L93, L98, R41

Keywords: Airport Development, Regional Economic Growth, China

Outline

1. *Introduction*
2. *Airport development and economic growth: a review of literature*
3. *Airport development and regional economic growth in China*
4. *Methodology and data*
5. *Hypotheses and empirical models*
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Non-Technical Summary

The Chinese civil aviation industry has achieved phenomenal growth over the last thirty years under economic reforms, especially from the 1990s. During 1990-2005, air cargo transport increased 17.53% per annum, which was substantially higher than all the major industrialized economies such as the US and the UK. Air passenger volume, measured in passenger-km, was 6.5 percentage points higher in China than the world average.

Like economic development, airports are not evenly distributed across the country. In addition, air traffic is not evenly spread out among the airports. There are huge congestion and flight delays among some airports. Much of the problem has been caused by the unexpected growth of demand. For other airports, the growth of business is slower than expected, resulting in significant excess capacity.
To solve the problem of poor planning and forecasting, the Eleventh Five-Year Plan (2006-2010) of China's civil aviation industry has pledged to invest RMB140 billion to expand Beijing Capital Airport, Shanghai Pudong Airport and Guangzhou Baiyun Airport, and to build 42 new airports, making the total number of airports 186 by 2010. The mismatch of airport construction, economic development and demand for air traffic suggests that it is important to understand the many factors that drive the demand for airport handling capacity. Such factors include population density, openness of the local regions, ground-transport and economic growth.

In China it is critically important for policy makers and airport managers to be well informed. As a result, a careful analysis on the interaction between airport development and economic activities is warranted to lay down appropriate planning, particularly, in the context of the national and regional space-economy. This study is precisely aiming to provide a solid empirical analysis based on an augmented production function to help policy makers on the construction or expansion of airports in different parts of the country.

The empirical data are collected for all the main airports in China during 1995-2006. The data also include regional level economic and geographical information directly or indirectly related to airport development. The panel data are used to construct an augmented Cobb-Douglas production to identify the key factors that influenced airport production measured by the volumes of passengers and cargo. It will answer the question whether it is reliable to forecast the development of airport and formulate strategic planning of airports according to GDP growth, or it is important to consider other variables than GDP growth.

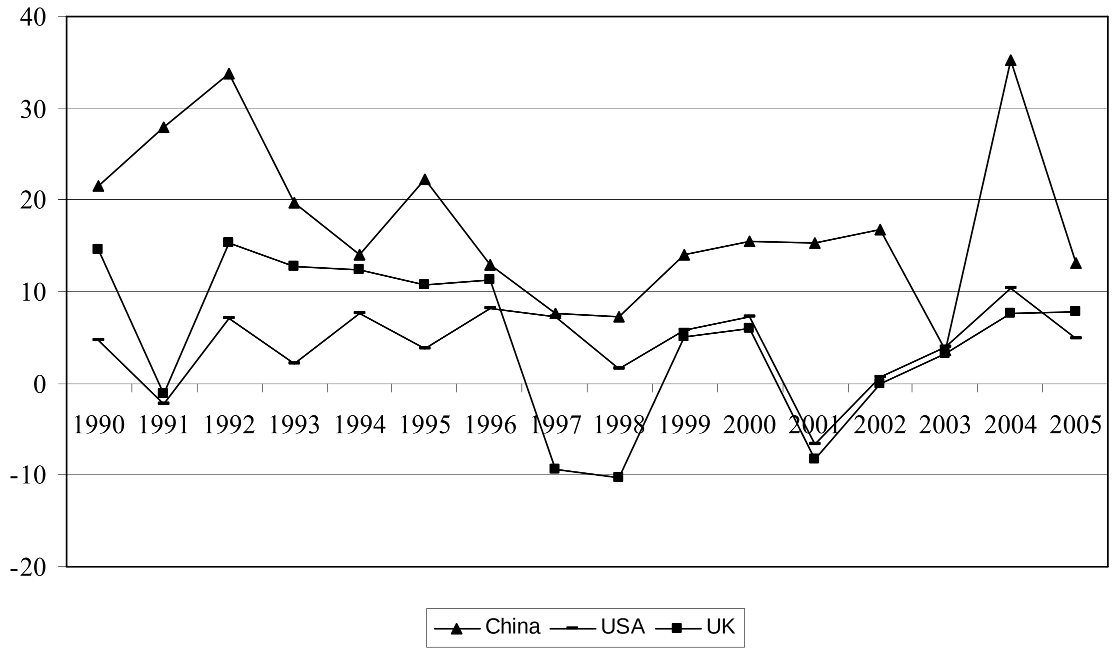
The estimation approach is based on the Engel-Granger error correction mechanism. Instead of following the traditional two-steps approach in the estimation, this paper uses the single-step approach to derive both the short-run and long-run elasticities of the concerned variables. The dependent variable is defined alternatively as the air passenger volume and the air cargo volume. The empirical results show that airport development is positively related with economic growth, industrial structure, population density, and openness, but negatively related with ground transportation. The results have important policy implications on regional airport development in China.

The growth of airport transportation in the eastern region is slower than in the inland areas, implying a more significant substitution effect of air transport on ground transport in the less densely populated areas, irrespective of economic activities. The results have useful policy implications as any regional transportation development plan has to simultaneously consider the competitive and supplementary effects of both air and land transports in a specific location.

1. Introduction

The Chinese civil aviation industry has achieved phenomenal growth over the last thirty years under economic reforms, especially from the 1990s. In 1990, China's air cargo volume was only 2.5 billion ton-kms, and air passenger volume was only 23.05 billion person-kms. By 2005, the respective figures surged to 26.1 billion ton-kms and 204.49 billion person-kms, making China the world's second largest air transport nation. Over this period, the average annual growth of air cargo transport was 17.53%, which was four times that of American's 4.14%, 3.6 times of UK's 4.86%, 5.3 times of Japan's 3.3% and 2.17 times of Germany's 8.09%. The average annual growth of air passenger volume, measured in passenger-km, was 6.5 percentage points higher than the world average (Planning and Development Division of CAAC, 2006). The significant growth differentials between China, the US and the UK in terms of air passenger-km are illustrated in Figure 1 for the data period 1990-2005.

Figure 1 Growth of the civil aviation industry of three countries (passenger-km growth, %)



Sources: CAAC, 1996-2006. *Civil Aviation Statistical Year book of China*

In 1994, the total number of passengers and cargo handled by China's airports were only 78.6 million persons and 9.1 million tons, respectively. By 2006, the respective volumes increased to 331.97 million persons and 75.3 million tons. Between 1990 and 2005, RMB120 billion was invested on constructing and upgrading 45 airports, and rebuilding more than 90 airports. By 2005, an extensive air transport network was completed, covering all the main cities throughout the country, including cities in the most remote and poorest areas in western China. By 2006, there were 25 size-4E international airports and 31 international airports. These airports have undergone continual development to cope with the dramatic growth of demand for air travel.

Like economic development, airports are not evenly distributed across the country. In addition, air traffic is not evenly spread out among the airports. There are huge congestion and flight delays among some airports such as Shanghai Pudong, Hangzhou Xiaoshan, Xi'an Xianyang, and Kunming. Much of the problem has been caused by the unexpected growth of demand. For instance, the expansion of Kunming Airport was started in 1997, with a total investment RMB9.98 billion for a designed capacity of 10 million passengers per year. In 1999, the new Kunming Airport was opened, but by 2005, its passenger traffic reached 11.81 million, exceeding its designed capacity by a great margin. In 2006, the State Council approved another expansion program of Kunming Airport, raising the total investment to RMB23.09 billion.

For other airports, the growth of business is slower than expected, resulting in significant excess capacity. Two such airports are Zhuhai and Fuyang. The expansion of Zhuhai Airport was started in 1994, aiming to increase its handling capacity from 0.73 million passengers in 1996 to 11.21 million by 2011, and from 12,000 tons of cargo in 1996 to 224,200 tons in 2011. The total investment of Zhuhai Airport was more than RMB 6 billion. In 2006, the number of passengers was 799,000 and the volume of cargo was 8,872 tons, both of which fell far short of the planned targets. Fuyang International Airport is one of the first three civilian airports in Anhui province. It cost RMB30 million to complete the expansion programme. In 2002, it handled only 920 passengers and was forced to cease operation in the same year.

To solve the problem of poor planning and forecasting, the Eleventh Five-Year Plan (2006-2010) of China's civil aviation industry has pledged to invest RMB140 billion to expand Beijing Capital Airport, Shanghai Pudong Airport and Guangzhou Baiyun Airport, and to build 42 new airports, making the total number of airports 186 by 2010. The mismatch of airport construction, economic development and demand for air traffic suggests that it is important to understand the many factors that drive the demand for airport handling capacity. Such factors include population density, openness of the local regions, ground-transport and economic growth. As pointed out by Goetz (1992) that building new airports or increasing airport capacity solely on the basis of promoting future growth may lack conclusive empirical foundation, unless the region is a strategic hub airport or has been a strong market demand for air travel. In China it is critically important for policy makers and airport managers to be well informed. As a result, a careful analysis on the interaction between airport development and economic activities is warranted to lay down appropriate planning, particularly, in the context of the national and regional space-economy. This study is precisely aiming to provide a solid empirical analysis based on an augmented production function to help policy makers on the construction or expansion of airports in different parts of the country.

The empirical data are collected for all the main airports in China during 1995-2006. The data also include regional level economic and geographical information directly or indirectly related to airport development. The panel data are used to construct an augmented Cobb-Douglas production to identify the key factors that influenced airport production measured by the volumes of passengers and cargo. It will answer the question whether it is reliable to forecast the development of airport and formulate strategic planning of airports according to GDP growth, or it is important to consider other variables than GDP growth.

The rest of the paper is organized as follows. The next section presents a literature review on transport economics relating to airport development. It will be followed by a discussion on research methodology, model specification, and the definition of variables in section 3. Section 4 analyses data and estimates the models. The final section draws conclusions and makes policy recommendations based on the empirical results and analysis.

2. Airport development and economic growth: a review of literature

There are many different studies on the importance of airport development to economic development, and the relationship between the development of civil aviation industry and economic growth, the privatization and commercialization reform of airports, the relationship between ownership and airport efficiency, airport congestion and resource allocation, and airport charges. But, to our surprise, a limited number of studies have looked at the impact of regional economic activities on airports to give government reliable information on airport construction and expansion. Especially, few studies can be found on the impact of regional economic activities on airport development in China.

Previous studies can be divided into two different schools. One school focuses on the relationship between airport activities and economic development (Goetz, 1992; Chou, 1993; and Green, 2002). The other school emphasizes the impact of airports on regional economic development (Bennell and Prentice, 1993; Robertson, 1995; and Debbage, 1999). For instance, Goetz (1992) studied the relationship between air passenger transportation and economic growth in the US urban system. His study found a positive and mutual interdependence between air transportation and urban economic growth. He argued that high air passenger index cities had high population and employment growth rates. His results suggest that economic growth affects airport development. Chou (1993) analyzed the distribution and accessibility of airports and found that the change of city air service nodes was the result of economic development and population growth, instead of the spoke-route structure operation. Green (2002) analyzed the relationship between airport activities and economic development in the US cities. His study revealed that air travel intensity (the number of air trips per head at a given period of time) is a powerful predictor of population and employment growth in the largest metropolitan areas.

The cost of airports is highly concentrated geographically while the benefits tend to diffuse throughout the community. This implies that policy relating to airport development has to be made at the regional or national level, rather than at the local or city level. Fleming and Ghobrial (1994) developed a model relating regional air travel demand to certain economic variables in the southeastern parts of the US. The results suggest that demand is relatively inelastic with respect to manufacturing shipments, tourism expenditures and statewide flight departures.

Bennell and Prentice (1993) examined the impact of airport activities on economic development in Canada and found that there was a significant effect of airports on employment in the country. They suggest that airports are an important driver of economic activities. Weisbrod (1993) studied how airports may affect the location choice of firms in the US. His result shows that employment growth within 6km of airports can be two to five times faster than in the suburban ring of the area in which they are located. Ivy et al. (1995) used data in 1978-1988 to analyze the relationship between the connectivity change of air transport services in the metropolitan areas of the US and employment. He found that the connectivity of air transport services in big cities influenced employment in central administration offices, and boosted the development of research institutions and the financial services sector. Especially, in agglomerative urban economies, a major airport can provide direct access to a wide variety of destinations, enhance the urban agglomerate economy and attract headquarters of MNCs into the local cities.

Robertson (1995) analyzed the effects of airports on the less buoyant areas in the UK. He contends that airports can aid regeneration of depressed areas. Airports can provide jobs for less skilled and unemployed workers and attract potential investments to the local regions. Debbage (1999) examined the linkage between airport operation and the structural composition of the regional economy. His main finding is that places experiencing significant increase in air passenger volume achieved considerable gains in employment, especially employment of administrative and auxiliary workers. The local economic structure of the largest and most competitive airport regions also experienced changes driven by airport operations. Airport development can increase economic activities through providing opportunities for new employment and investments in ground services, catering and retailing services. In the meantime, the air transportation network of a region can fundamentally alter its economic linkages with other regions and countries through the flows of goods and people. Button et al. (1999) in a study of the relationship between the hub airport and the employment in high-tech industries found that hubs create employment.

The studies by Chinese scholars about airports are different. They pay strong attention to the relationship between the development of civil aviation industry and national economic growth. Liu (2000) examined the relationship between the development of the civil aviation industry and GDP growth in China and did not find any positive relation between the two variables during 1985-1999. The average annual growth rate in the civil aviation industry was 1.5-2 times that of GDP. Yang and Wang (2006) analyzed the relationship between GDP, air cargo and passenger volumes from 1952 to 2004. They found that GDP growth had a significant effect on the growth of air travel. Ye, Li and Li (2005) conducted a cointegration test showing that GDP growth caused the growth in the civil aviation industry, but not the other way round.

Overall, existing studies show strong evidence that airport development has played an important role in stimulating regional and national economic growth through job creation and attracting the inflows of capital and new businesses to the regions close to airports. In addition, the construction and expansion of airports can also change the structure of local investment and employment. However to some extent, it is these studies that often induce governments to implement more ambitious airport development plans, investing vast amount of capital into new airport expansion and reconstruction. If a nation's transportation system is maturing and competition among different transportation modes is intensifying, the effects of airport development on the economy can become ambiguous.

In China in particular, policies should be more focused on the following key issues. First, how should CAAC (Civil Aviation Administration of China) and airport authorities prioritize investment opportunities to maximize short- and long-term economic growth? Second, what is the trade-off between additional economic growth and the cost of airport development? On the one hand, airport activities can create employment and attract new businesses to the vicinity of airports. On the other hand, regional economic structure, population and ground transport can also affect market orientation, investment, commercial activities and the agglomerative function of airports. This implies that policy-makers and scholars should not only understand the influence of airports on additional economic development; but also the effects of economic activities on the demand for air transport and the competition among different transport modes. As far as the relationship between Chinese airport industry and regional economic growth is concerned, there are few studies paying sufficient attention to the second part of this question, i.e., how do economic growth and the local economic conditions affect airport development in China?

The decision on and planning of airport development is not to simply decide which airport needs to be expanded or where to build a new airport. It is more a question of how the expansion of an existing airport or the construction of a new one can impact upon the local economy in the most efficient way, taking into account of the existing economic structure, topography, population density, and the substitutability/complementarities of other modes of transport. In a fundamental cost-benefit framework, airport is not only an important impetus of economic growth but also a cost to the economy because it requires large investments. Consequently, it is important to take a holistic and comprehensive approach in order to minimize the costs of wrong decisions on airport planning and to maximize the efficiency of airport development and operation.

The principal research question in this paper is to understand the fundamental interconnections among airport development, economic growth, economic structure, population and ground transport in the Chinese regions. To answer this question, the paper will identify the determinants of airport development and explain why airports are unevenly distributed across the regions. The key objective is to establish a baseline between airport management, local government and other stakeholders for coordinating future airport development. Another objective is to provide policy recommendations for government officials and airport managers regarding the future direction of airport planning and development.

3. Airport development and regional economic growth in China

The monopoly of regional airports determines the inextricable linkage between airport development and regional economic development. The airport industry in China has grown more rapidly than the national economy over the last three decades. Over the data period 1995-06, the air passenger volume grew by 13.74% and the air cargo volume by 12.56% per year (Table1). The airport industry used to be controlled by the central government, but from 2001, a *blanket* localization reform was started to decentralize the operation and management of regional airports in an effort to promote efficiency and encourage the participation of regional governments.

The localization reform has incorporated airport development into regional economic development, providing strong incentives for local authorities to commit more investments and preferential policies on airport development. Consequently, the pace of airport construction and expansion has been greatly accelerated across the country since 2001. Before 2001, the annual growth rates of air passenger and cargo volumes were 8.48% and 10.32%, respectively. After 2001, the corresponding growth rates were 18.99% and 14.8%.

Table 1 Air transport and economic growth in China, 1995-2006 (% per year)

Province	Passenger			Cargo			GDP
	1995-01	2001-06	1995-06	1995-01	2001-06	1995-06	1995-06
Beijing	7.6	12.9	10.2	9.1	15.8	12.5	13.3
Fujian	-2.2	13.0	5.4	-1.6	12.5	5.5	11.2
Guangdong	4.2	14.3	9.3	11.6	12.3	12.0	13.0
Hainan	10.6	13.7	12.1	10.9	7.2	9.1	9.8
Hebei	-1.2	21.9	10.3	21.6	-11.7	4.9	11.2
Jiangsu	4.0	19.6	11.8	10.0	24.7	17.3	12.4
Shandong	11.2	19.3	15.3	11.7	18.1	14.9	12.3
Tianjin	3.9	22.1	13.0	52.0	15.4	32.5	13.2
Zhejiang	4.4	19.9	12.2	10.4	16.1	13.2	12.5
East	***4.7***	***17.4***	***11.1***	***15.1***	***12.3***	***13.7***	***12.1***
Anhui	2.8	15.3	9.0	2.9	15.5	9.2	10.6
Henan	4.6	17.9	11.3	8.9	18.3	13.6	11.1
Hubei	18.2	23.3	20.8	0.9	18.7	9.8	11.7
Hunan	8.8	21.7	15.2	2.3	23.3	12.8	10.7
Jiangxi	2.1	24.0	13.1	-3.6	26.9	11.7	11.5
Shanxi	2.8	36.9	19.8	19.1	-3.3	7.9	12.3
Central	***6.6***	***23.2***	***14.9***	***5.1***	***16.6***	***10.8***	***11.3***
Heil'gjiang	1.1	15.3	8.2	-1.6	12.8	5.6	9.1
Jilin	5.5	13.9	9.7	0.8	16.3	8.5	11.0
Liaoning	27.6	14.9	21.2	34.9	12.4	23.7	11.0
Northeast	***11.4***	***14.7***	***13.1***	***11.4***	***13.8***	***12.6***	***10.4***
In Mongolia	10.1	25.8	18.0	42.3	11.3	24.5	14.8
Chongqing	5.5	13.9	9.7	0.8	16.3	8.5	10.1
Gansu	9.3	17.0	13.1	5.2	17.9	11.5	10.3
Guangxi	5.6	11.8	8.7	3.7	9.4	6.5	10.1
Guizhou	10.2	18.8	14.5	9.9	19.0	14.5	10.0
Ningxia	16.8	25.6	21.2	9.9	37.2	23.5	11.2
Qinghai	27.0	25.6	26.3	11.8	25.0	18.4	11.9
Shaanxi	10.2	16.9	13.6	5.8	13.5	9.6	11.1
Sichuan	6.4	21.8	14.1	8.5	15.5	12.0	10.5
Tibet	12.9	13.3	13.1	2.0	7.8	4.9	11.8
Xinjiang	5.2	24.4	14.8	12.3	12.3	12.3	9.4
Yunnan	15.6	17.0	16.3	21.4	13.4	17.4	9.3
West	***11.2***	***20.7***	***16.0***	***9.8***	***16.5***	***13.2***	***9.6***
All China	***8.5***	***19.0***	***13.7***	***10.3***	***14.8***	***12.6***	***10.8***

Notes: Air passenger volume is measured in person-km and air cargo volume in ton-km. All the figures in this table are average annual growth rates.
Sources: CAAC (1996-2006) *Civil Aviation Statistical Year book of China.* CAAC (2007)The statistics of aviation airport production of 2006. NBS (1996-2006) *China Statistical Yearbook.* NBS (2005).*China Statistical Data of 55 Years1949-2004.* NBS (2006) *National Economic and Social Development Communiqué of Every Province in 2006.*

Table1shows that regional growth differences in air transport are different from the growth differences of other economic activities such as FDI and investments (Yao and Wei, 2007). In China, the highest FDI and investment growth provinces are concentrated in the eastern coast, but the highest growth provinces of air passenger volume are concentrated in the western provinces, especially after 2001. The average annual growth of air passenger volume was 1.7 percentage points higher in the west than the national average although the average annual GDP growth in the west is significantly lower than the national average. In other words, the growth of air passenger volume is not necessarily determined by economic growth alone. Factors such as population density and the availability of ground transport are also important in the determination of air passenger volume.

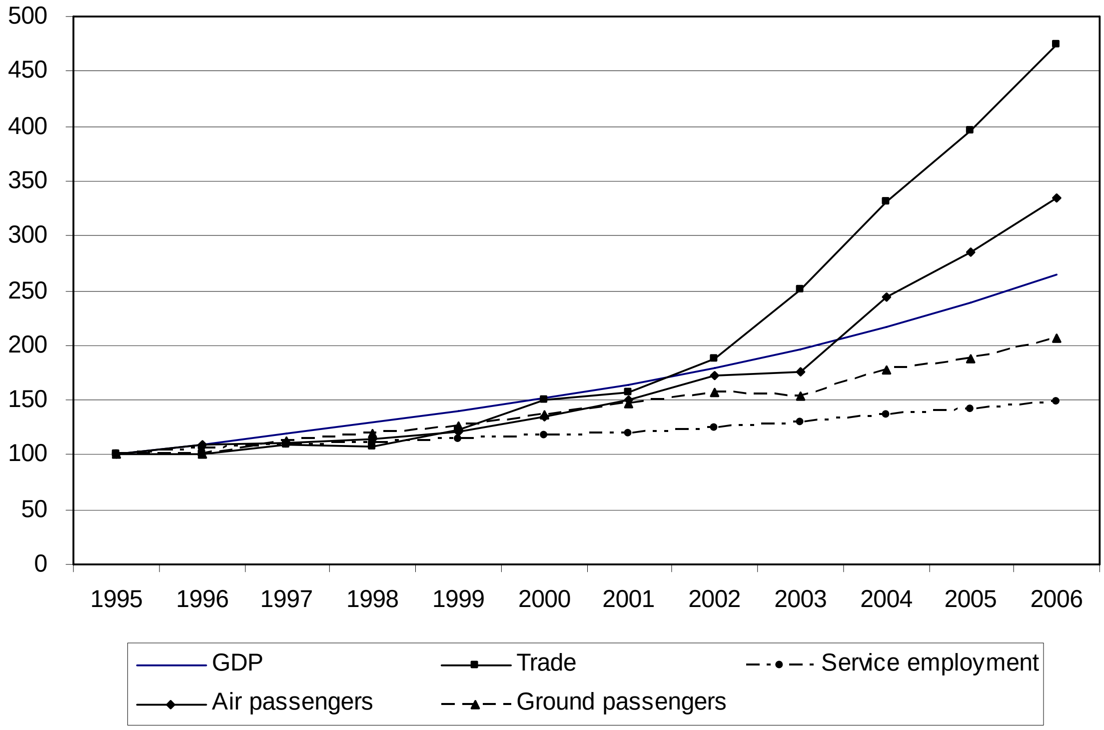
By contrast, the regional growth differences of air cargo volume resemble those of economic growth (column 7 in Table 1). High economic growth is directly linked to high growth in air cargo volume. However, from 2001 to 2006, the growth of air cargo volume in the east was slower than in the other three regions (column 5, Table 1).

Rapid economic growth has resulted in significant structural change in the national and regional economies. In principle, the shares of agricultural production and employment as a proportion of the national total have declined while the shares of non-agricultural production and employment increased over time. One hypothesis to be tested in the empirical model is that this structural change can also influence the level of airport development.

Figure 2 show the trends of real GDP, real import and export, employment of the tertiary industry, ground and air passenger volumes. All the variables are aggregated at the national level and converted into real values in 1995 prices. It appears that air transport is not only associated with economic growth but also with other variables such as openness, ground transportation and economic structure.

Over the data period, China's airport industry experienced two stages of reform. The first stage of reform, from 1995 to 2001, was characterized by a joint-equity and localization reform. Thirty-five airports were transferred from central administration to regional authorities and most airports were changed into joint-equity companies over the period. The second stage of reform from 2001 has been characterized by further deregulation of airport operation and ownership diversification. The blanket localization reform has been carried out to encourage local authorities to accelerate airport development and financing.

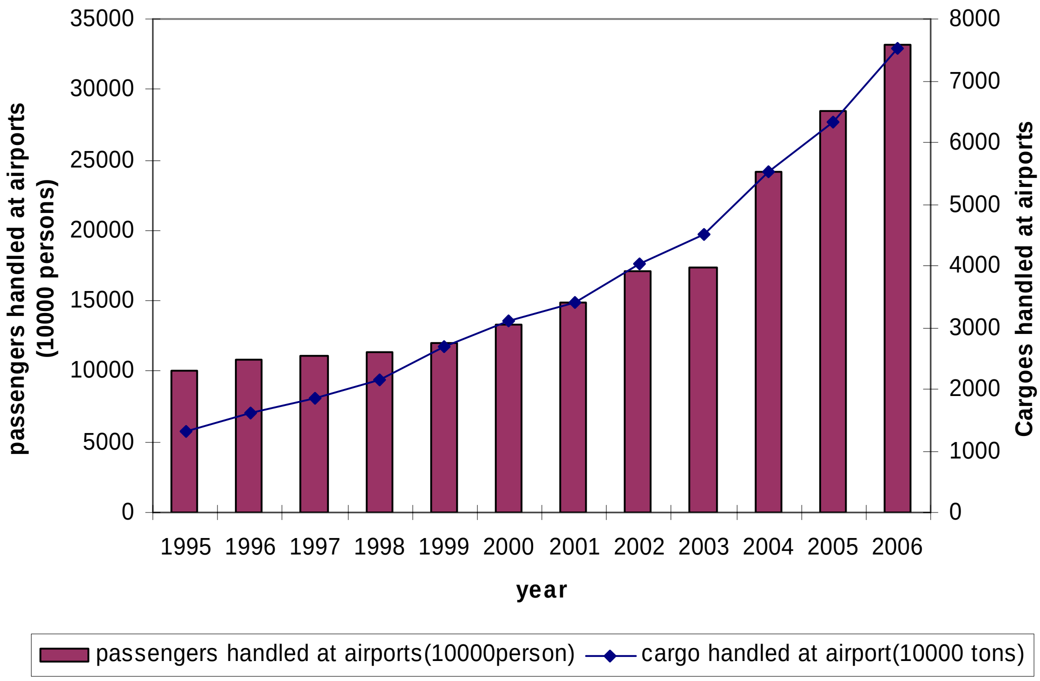
Figure 2 Trends of GDP, trade, employment of tertiary industry, ground and air passenger volumes (indexes, 1995 = 100)



Notes: All values are measured in 1995 constant prices and converted into indexes (1995=100). Employment of tertiary industry is measured as the share of employment in the tertiary industry in total employment.
Sources: CAAC (1996-2006) *Civil Aviation Statistical Year book of China.* CAAC (2007) The statistics of aviation airport production of 2006. NBS (1996-2006) *China Statistical Yearbook.* NBS (2005) *China Statistical Data of 55 Years1949-2004.* NBS (2006) *National Economic and Social Development Communiqué of Every Province in 2006.*

The reforms have resulted in a rapid growth in air transport in China, especially during the second stage of reforms from 2001. Figure 3 shows that the total number of passengers handled by China's airports increased from 100 million in 1995 to 125 million in 2000 and then rocketed to 330 million in 2006. The volume of air cargo increased even faster, rising from 60 million tons in 1995, to 130 million tons in 2000 and then to 330 million tons in 2006. The acceleration of air traffic growth from 2001 implies that institutional reforms and regulatory policies must have had important effects on airport development apart from economic growth and structural change.

Figure 3 Development of China's air transport industry (1995-2006)



Sources: CAAC (1996-2006) *Civil Aviation Statistical Year Book of China.* CAAC (2007) The statistics of aviation airport production of 2006.

4. Methodology and data

Econometric models using panel data which pulls time series and cross-sectional data together tend to have two econometric problems. The first results from the non-stationary nature of time series. If the variables in the equation are non-stationary and not co-integrated, the regression results can be spurious. As a result, the first step of model estimation is to make sure that the variables must be integrated if they are found to be non-stationary. The second results from the potential endogeneity of explanatory variables.

The econometric technique that can resolve the above-mentioned problems is the Generalized Method of Moments (GMM) proposed by Arellano and Bond (1991), and Arellanno and Bover (1995), which provides unbiased and efficient estimates. These authors suggest first differencing the model to get rid of the individual specific effects and then using valid instruments to control for the potential endogeneity of explanatory variables.

A drawback of the difference GMM estimator is that when first differences are taken, time invariant variables are wiped out. So, the estimator does not use the cross-sectional information reflected in the differences between regions. Another disadvantage is that lagged levels are often poor instruments for the equation in differences, especially in the case of panels with a small number of time periods with highly persistent data, which can lead to large finite sample biases and poor precision in the estimators.

One alternative econometric technique to deal with the problem of endogeneity is to use the Engel-Granger's (1987) two-step error correction mechanism (ECM) and the generalized error correction method (GECM) suggested by Banerjee et al. (1993) to test whether the concerned variables are really cointegrated in the long-run model. Error correction mechanism is based on the assumption that two or more time series exhibit an equilibrium relationship that determines both short and long-run behavior. Error correction model will prove the degree to which the equilibrium drives short-run dynamics (Suzanna De Boef).

Engel-Granger's two-step error correction model (ECM) for cointegration analysis proceeds as follows. The first step is running a regression of equation (1), the long-run model, to derive the residuals ($\hat{u}_{it}$) and test whether this series of residuals is stationary.

$$y_{it} = \beta_0 + \beta_1 x_{it} + \mu_{it} \qquad (1)$$

Where all the variables are in logarithms, β's are a set of coefficients, x_{it} a vector of explanatory variables for y_{it}, and μ_{it} residuals. The subscripts i and t denote region and time, respectively.

If $\hat{u}_{it}$ shows short memory, it expresses that the time series are cointegrated and the second step of estimation can proceed to estimate the equilibrium rate θ and short-run dynamics λ_1 from equation (2) below.

$$\Delta y_{it} = \lambda_0 + \lambda_1 \Delta x_{it} - \theta \hat{\mu}_{it-1} + v_{it} \qquad (2)$$

Where Δy_{it} denotes the changes of the dependent variable, Δx_{it} denotes a vector of the changes of the explanatory variables. Actually, equation (2) is the short-run (first differences) formation of the long-run model expressed in equation (1). The ECM is represented by the lagged term of the estimated residuals derived from the regression of the long-run equation ($\hat{\mu}_{it-1}$). If θ is found to be significant and positive, it means that there is a long-run cointegration relationship among the variables specified in equation (1). One problem of Engel-Granger's two-step error correction model is that the long run coefficients cannot be estimated. To solve this problem, Banerjee et. al. (1993) suggested the generalized one-step error correction model as shown in equation (3).

$$\Delta y_{it} = \lambda_0 + \lambda_1 \Delta x_{it} - \theta(y_{it-1} - \beta x_{it-1}) + v_{it} \qquad (3)$$

The error correction term is given by $(y_{it-1} - \beta x_{it-1})$, θ is the estimated correction rate. The short-run coefficients are λ_1 which is a row vector of coefficients on the column vector of explanatory variables Δx_{it} .The dependent and explanatory variables will be cointegrated if the long-run coefficients (β's) and the rate of error correction coefficient θ are jointly significant.

Unlike the two-step model, the one-step dynamic single-equation GECM model has several advantages. First, it can estimate the short-run dynamics, long-run relationship and the disequilibrium simultaneously. Second, non-stationary and simultaneous problems can be avoided because all the variables are presented in their first (log) differences and pre-determined values (lagged terms). Third, it requires no restriction on the ADL (autoregressive distributed lag model) so that the ECM representation is used in re-equilibration (Boef, 2000). Finally, it substantially simplifies the estimation procedure and the estimated results are easy for interpretation.

The data is based on a panel of 31 provinces and municipalities for the period 1995-2006, including all airports in operation over the entire data period. The data for the explanatory variables over the period 1995-2005 are extracted from the *China Statistical Yearbook* (NBS, various years, 1996-2006) and *China Statistical Data of 55 Years 1949-2004* (NBS, 2005). The same data in 2006 are obtained from *National Economic and Social Development Communiqué* of individual provinces and municipalities. The airport production data over the period 1995-2005 are derived from *Statistical Data on Civil Aviation of China*. The same data in 2006 are obtained from *Statistical Bulletin of Chinese Airport Production in 2006*. Although Chongqing City was established in 1997, it is possible to obtain its own data separated from Sichuan for 1995 and 1996. As a result, Chongqing is included as a region separated from Sichuan.

All the values during the data period are calculated at the constant prices based in 1995. GDP are measured in 100 million RMB, converted into 1995 prices using provincial level GDP deflators. Exports and imports are measured in nominal US dollars but they are deflated by the CPI in the US based in 1995. The deflated values are converted into equivalent values in RMB by multiplying the official exchange rate in 1995 ($1= RMB 8.4). To test whether there is any regional effect on airport development, the 31 provinces and cities are grouped into four large geo-economic regions: east, central, west and north-east.1

In the regression model, regional and time dummies are used. East takes the value of 1 for an eastern province and 0 otherwise, west takes the value of 1 for a western province and 0 otherwise, north-east takes the value of 1 for a north-east province and 0 otherwise. Central is the benchmark. In order to reflect the impact of airport reform, time 1995-2001 takes the value 1 for the period 1995-2001 and 0 otherwise. Fourth, because airports within a province or a municipality reflect a single market for air services, it combines passenger volume and cargo volume of airports in one province together to get a consolidated province level of aggregation.

5. Hypotheses and empirical models

Variables

Previous studies have showed a close relationship among regional GDP, population, location and airport business (Debbage, 1999; Green, 2002). Apart from GDP, population and location, this paper assumes that other factors such the regional economic structure and ground transportation systems are two other relevant and important variables influencing airport development.

GDP reflects the level and scale of regional economic development. High regional GDP means high income level, which is a key determinant of air travel demand. Industrial structure also indicates the level of industrialization and economic development of a particular region. The change in regional economic structure can boost the level of demand for air transport. When a region has achieved a higher level of industrialization, the shares of high-technology industries and tertiary services in the regional GDP will increase. This,

[1] East includes Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. Central includes Shanxi, Inner Mongolia, Anhui, Jiangxi, Henan, Hubei and Hunan. West includes Chongqing, Sichuan, Guizhou, Yunnaan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. Northeast includes Liaoning, Jilin and Heilongjiang.

in turn, will promote airport development as the demand for air travel is likely to increase. Weisbrod (1993) shows that business activities attracted to airports are high-tech electronics, specialized equipment manufacturers, communications companies, data processing services, head-quarters of large national and multi-national companies.

Air transport, highway, railway and waterway are alternative modes of transportation. They can be competitive and or supplementary, depending on the local geo-economic conditions and the relative costs and benefits of modes of transport. For example, if the cost of air transport is much higher than that of railways, passengers may choose to travel by train instead of air even though traveling by train may take a much longer time than by air. In this case, railway must be a competitor of airway. In another example, if road or railway are poorly developed and the time spent on the train or bus is substantially longer than traveling by air, then it is likely that passengers will have to travel by air even if it is much more expensive than ground transport. In this regard, ground transport may not be an effective competitor of air transport. To some extent, it may be possible that the coexistence of both air and ground transports are supplementary for a particular region where ground transport is prohibitively difficult and inconvenient.

Another variable that is relevant and important for the demand of air transport is openness, represented by export intensity of a region. If a region is more open, and hence more engaged in international trade, it is expected that there will be more demand for air transport. As a result, the empirical model will need to incorporate this openness variable.

In China, economic development is unevenly spread across the country. This issue must also be relevant to airport demand. In the empirical model, regional dummy variables, representing the east, central, west and the northeast will be included into the empirical model. It is hoped that these regional variables will be used to explain the 'un-explained part' of the dependent variable by those economic variables discussed above.

Based on the above discussion, it is useful to present a few hypotheses to be tested in the empirical model. These hypotheses are based on a thorough literature review relating to airport development in China and elsewhere in the world. They are also based on our previous studies on the real economic situation in China.

Hypothesis 1: It is assumed that there exists a positive relationship between the level of economic development and air travel demand for both passengers and cargo. The level of economic development is represented by GDP.

Hypothesis 2: The growth of demand for air travel in terms of passengers and cargo is dependent on the growth of economic activities, or the growth of GDP.

Hypothesis 3: The demand of air travel in both passengers and cargo is positive related to population density. In other words, demand for air travel is higher in a region if that region has a higher population density than another region.

Hypothesis 4: The relationship between air and ground transports is substitutable in general and complementary only if ground transport is prohibitively difficult due to topography and poor ground transportation system.

Hypothesis 5: The demand for air transport increases if the region becomes more open in terms of international trade.

Hypothesis 6: Economic structure can affect airport business. If a region is more dominated by the services industry, its air travel demand will be higher than in other regions.

Hypothesis 7: Institutions, regulations and government policies can help promote air transport development. It is anticipated that the reforms from 2002 characterized by localization and decentralization of government regulatory policies must have had a positive impact on airport development in China.

With these hypotheses, it is now possible to derive an empirical model for analysis. The dependent variable of the model will be defined in two forms: the volume of passengers and the volume of cargo by air. The explanatory variables will include GDP, population density, openness (trade/GDP), economic structure (share of employment accounted for by the tertiary industry), ground transportation (volume of rail and road transport), location dummy variables (east, northeast and west, using central as a base), and a time dummy for 1995-2001.

The final empirical model can be specified in equation (4) below.

$$y_{it} = \alpha_0 + \alpha_1 gdp_{it} + \alpha_2 services_{it} + \alpha_3 pd_{it} + \alpha_4 gt_{it} + \alpha_5 trade_{it} + \alpha_6 east + \alpha_7 west + \alpha_8 northeast + \alpha_9 9501 + \mu_{it} \qquad (4)$$

All the variables are in natural logarithms. The subscripts (i=1,2,...,31) and (t=1,2,…,2006) denote province *i* and year *t; y* is dependent variable, representing the volume of air passengers or the volume of air cargo; *gdp* the level of GDP; *services* the share of services sector employment in total regional employment; *pd* population density measured in persons per squared km; *gt* ground transport, if *y* is the volume of air passengers (cargo), it is the volume of passenger-kms (freight ton-kms) traveling by train or by road; *trade* is measured as trade/GDP ratio, and trade is the total volume of imports and exports; *east*, *west* and *northeast* are respectively the dummy variables for the east, west and northeast regions, using the central region as a reference; *9501* is the dummy variable for the period 1995-2001; μ_{it} is an error term. The summary statistics of all the variables involved in the models are presented in Table 2.

Table 2 Summary statistics (12 years, 31 provinces, 1995-2006)

Variable	Observations	Mean	SD	Min	Max
Air passengers	372	14.74	1.32	10.98	17.71
Air cargo	372	10.61	1.52	6.07	14.74
GDP	372	7.71	1.10	4.06	10.03
Ground passengers	367	10.11	1.14	5.66	11.96
Ground freights	367	10.79	1.09	6.04	12.66
Population density	371	5.22	1.47	0.68	7.96
Trade/GDP	372	-1.88	1.01	-3.44	0.72
Services	341	-1.26	0.25	-1.94	-0.32

Notes: (1) All the values are in natural logarithms and in 1995 constant prices in million RMB (GDP). (2) Air passengers and cargo are measured in person-kms and ton-kms. Ground passengers and freights are also measured in person-kms and ton-kms. (3) Trade/GDP is the values of exports and imports divided by GDP. (4) Services = the share of tertiary sector employment in total employment. (5) SD = standard deviation. Min and Max are minimum and maximum values of the respective variable in the data set.

Source: CAAC (1996-2006) *Civil Aviation Statistical Year book of China.* CAAC (2007) Statistics of aviation industry production of 2006. NBS (1996-2006). *China Statistical Yearbook.* NBS (2005).*China Statistical Data of 55 Years1949-2004.* NBS (2006) *National Economic and Social Development Communiqué of Every Province in 2006.*

Equation (3) is estimated in its level form (long run model) for both the air passenger and air cargo volumes using the random dummy OLS technique. The results for these two different dependent variables are presented in Table 3.

Table 3 Panel data regression results

Dependent variables	Air passengers		Air cargo	
	coefficient	t-value	coefficient	t-value
constant	11.37	18.45***	8.62	15.69***
GDP	0.84	4.67***	1.48	14.15***
Population density	0.17	3.58***	0.12	2.66***
Trade/GDP	0.80	7.55***	0.75	7.45***
Services	0.23	1.03	0.67	2.82***
Ground passengers	-.22	-2.16**		
Ground freights			-0.77	-10.28***
West	0.82	7.51***	0.94	8.77***
East	-.85	-2.82***	-0.59	-2.91***
Northeastern	-0.13	-1.00	-0.002	-0.01
1995-2001	-0.14	-1.14*	0.24	2.67***
Diagnosis	R^2=0.63 t =12 n=341		R^2=0.78 t =12 n=341	

Notes: (1) All the values are in natural logarithms and in 1995 constant prices in million RMB (GDP). (2) Air passengers and cargo are measured in passenger-kms and ton-kms. Ground passengers and freights are also measured in passenger-kms and ton-kms. (3) Trade/GDP is the values of exports and imports divided by GDP. (4) Services = the share of tertiary sector employment in total employment. (5) West, East and Northeast are regional dummy variables. They take the value of 1 if the province is located in that region and 0 otherwise. The central region is a reference region in both models. (6) '***', '**' and '*' signify respectively the significance levels of 1%, 5% and 10%.

Both dependent variables are well explained by the explanatory variables. In the air passenger equation, the goodness-of-fit is 63% and in the air cargo equation 78%. All the explanatory variables are statistically significant at the 1% or 5% levels except the northeastern dummy in both equations, service sector employment in the air passenger equation and the time dummy variable in the air passenger equation which is significant at the 10% level. In addition, all the estimated coefficients have the expected signs as presented in the seven hypotheses discussed in the previous section except the time dummy variable in the air cargo equation.

GDP representing market size and the level of economic development is found to have a highly significant and positive impact on both air passenger and cargo volumes. The estimated coefficients are significant at the 1% level and their sizes are large as well. They imply that for every 10% increase in a regional GDP, the volume of air passengers will increase by 8.4% and that of air cargo by 14.8%, holding other conditions unchanged.

Population density is another important variable. The estimated coefficients are significant at the 1% critical level. The close relationship between population density and the intensity of air travel is revealed by the relative large sizes of the estimated coefficients which imply that if population density increases by 10%, air passenger volume will increase by 1.7%

and air cargo 1.2%. In China the most densely populated regions are along the south and eastern coasts of the country. These regions are the economically more advanced and open areas in China. The positive relationship between population density and air travel may suggest that these regions are more developed in air transportation than the rest of the country. However, the data used for the models are provincial level data. Population density is a more relevant indicator reflecting an increase in demand in those provinces whose populations are large, especially when other variables such as regional dummies and ground transportation are included in the same regression model.

The trade/GDP ratio which reflects the degree of openness is found to have a significant and sizeable impact on air transport. The estimated coefficients are significant at the 1% critical level and the sizes are large in both equations. The coefficients imply that if the trade/GDP ratio rises by 10%, the air travel will increase by 7.5% in cargo volume and 8% in passenger volume.

The share of service sector employment in total employment is found to have a significant impact on air cargo volume but not on air passenger volume. If the share of service sector employment in total employment increases by 10%, air cargo volume will increase by 6.7%. The effect of this same variable on air passenger volume is statistically insignificant. Employment in the services industry is used to represent the differences in economic structure among the provinces. It is assumed that if this variable is higher, the level of economic development in that region will also be higher. As the level of economic development can also be reflected in other explanatory variables such as the trade/GDP ratio and regional dummies, it may not be surprising if this variable is found to have a lesser effect on air travel. Nevertheless, this variable is still found to have a significant impact on air cargo volume. As a result, it shows some evidence that economic structure is a relevant variable influencing the demand for air transport in general and in cargo transport in particular.

Ground transportation in terms of freights and passengers are found to be significant substitutes for the respective air cargo and passengers. The estimated coefficients are negative and significant at the 5% or 1% critical level. The substitution effect in cargo/freights transport is far more significant and sizeable than in air/ground passenger transport. If ground freight transport increases by 10%, air cargo transport will decline by 7.7%. If ground passenger volume increases by 10%, air passenger volume will decline by just 2.2%. This means that although ground transport is a significant substitute for air transport, passengers tend to be more attracted by air transport than freights as time-saving is probably more valuable to people than to freights/cargo.

The estimated coefficients on the regional dummy variables are very interesting in the sense that their signs do not reflect the level of economic development of the respective regions. For instance, the signs of the eastern dummy variable are negative in both equations but this region is economically far more advanced than the reference region, the central region. This means that, *ceteris paribus*, demand for air transport would be significantly less in the east than in the central (and west) region. The most likely explanation for this is that the central region has a lower population density and a less developed ground transportation system than the east region. As a result, air transport in the central would be more attractive than in the east due to the complementary effect of air transport for ground transport.

The same explanation can be applied to the estimated coefficients of the west dummy in the equation. Unlike the east region, the west region is less developed than the reference region, but the estimated coefficients are significant and positive. This also implies that, *ceteris paribus*, demand for air transport would be significantly more in the west than in the central (and east) region. This is because ground transport must be significantly less developed in the west and its population is significantly less densely populated than in the central (and east) region. As a result, air transport is relatively more economical and attractive in the west as it is a good supplementary mode of transport for railways and highways.

Finally, the estimated coefficients of the time dummy variable for the period 1995-2001 are found to be negative and significant at the 10% level in the air passenger volume equation. This result supports the last hypothesis that decentralization of airport management and regulations from 2001 must have helped accelerating airport development in China. This hypothesis, however, is not supported by the estimated coefficient of the same time dummy in the air cargo volume model. The coefficient is positive and significant, suggesting that the reform from 2002 had actually slowed down the development of air cargo transport. Nonetheless, this result has to be explained with caution. One possible explanation for this is that China has undergone an ambitious railway and highway expansion and enhancement programme from 2001, coinciding with the de-regulation and decentralization of airports. The rapid increase in the total length of railways, motorways and other highways, as well as the speed-raising of the national rail network, in addition to the increased use of cold storage and refrigeration in ground transport, must have reduced the cost and waste of ground transport to make it more competitive compared to air cargo transport. For instance, a recent informal interview conducted by the authors in Xi'an International Airport revealed that the amount of fresh seafood transported by air declined steadily over the last five years because merchants preferred to use cold storage facility to transport seafood by train at much lower cost.

The long-run models estimated in Table 3 may be subject to some econometric problems as mentioned previously if the variables are not cointegrated and/or if some of the explanatory variables are endogenous. To test whether the variables are co-integrated and to make sure the results in Table 3 are not spurious, the DECM models are estimated below. Instead of following Engel-Granger's two steps approach to estimate the error correction model, the one step approach is adopted in the estimation based on equation (3) presented in the previous section. The estimated results for both air passenger and air cargo volumes are presented in Table 4.

The definitions of variables in Table 4 are given at the notes to Table 3. It is stressed here that all the variables are in natural logarithms and measured in 1995 constant prices. The dependent variables are the first differences of air passenger and cargo volumes. For each model, there are two versions of estimation. One is a short-run model (first differences of the long run model) shown in equation (2). The results of the short-run (first differences) models are presented in the second column (air passenger) and the fourth column (air cargo) of the table. The GECM models are based on equation (3) which incorporates the short-run models with ECM comprising of the lag term of the long run error expressed as the difference between the dependent variable and the right hand side variables in the long run model. The GECM results are presented in the third column (air passenger) and the last column (air cargo) of the table. The short-run and long-run elasticities are summarized in Table 5.

Table 4 Regression results using GECM

Dependent variables	ΔPassenger		ΔCargo	
	Short-run	with ECM	Short-run	with ECM
Constant	0.0054 (0.10)	0.4563 (2.21***)	0.0636 (0.46)	1.1579 (2.97***)
ΔGDP	1.3168 (3.07***)	0.9723 (2.12***)	0.7675 (0.67)	-0.4233 (-0.42)
ΔPopulation density	0.1386 (0.38)	0.3817 (0.99)	-0.9852 (-1.36*)	0.0027 (0.00)
Δtrade/GDP	0.0696 (1.79*)	0.0706 (1.49*)	-0.1059 (-1.01)	-0.1028 (-0.91)
ΔServices	0.0417 (0.24)	0.1233 (0.62)	0.0563 (0.15)	0.15 (0.39)
ΔGround passengers	0.1043 (1.21*)	0.1168 (1.33*)		
ΔGround freights			-0.146 (-0.99)	-0.07 (-0.49)
western	0.0281 (1.36*)	0.0406 (1.38*)	0.0017 (0.03)	0.1427 (2.28***)
eastern	-0.0059 (-0.23)	-0.0232 (-0.39)	0.0267 (0.50)	-0.0103 (-0.10)
Northeastern	-0.0047 (0.21)	-0.0026 (-0.07)	-0.0144 (-0.30)	0.0052 (0.9)
1995-2001	-0.0706 (-3.54***)	-0.0894 (-5.12***)	-0.0392 (-0.78)	-0.048 (-1.07)
EMC				
Air passenger_1		-0.0373 (-3.38***)		
Air cargo_1				-0.1503 (-3.58***)
GDP_1		0.059 (2.32**)		0.169 (2.22**)
Population density_1		0.0495 (0.50)		0.0318 (1.51*)
Trade/GDP_1		0.0448 (1.9**)		0.1011 (2.05**)
Services_1		0.0377 (0.76)		0.1889 (0.18)
Ground passenger_1		-0.0043 (-0.26)		
Ground freight_1				-0.0635 (-1.54**)
Diagnosis	R^2=0.1529 t =12 n=308	R^2=0.191 t =12 n=308	R^2=0.0142 t=12 n=309	R^2=0.1179 t=12 n=335

Notes: (1) All the notes in Table 3 apply in Table 4. (2) t-values are in parentheses; '_1' means lags one period; 'Δ' means first differences.

Table 5 Short-run and long-run elasticities

Variables	Air passenger		Air cargo	
	short-run	long-run	Short-run	long-run
GDP	1.3168***	0.5737**	0.7675	1.124***
Population density	0.1386	0.1327	-0.9852*	0.2116*
Trade/GDP	0.0696**	0.8217**	-0.1059	0.6727**
Services	0.0417	1.01	0.0563	1.2568
Ground passengers	0.1043*	-0.1153*		
Ground freights			-0.146*	-0.0422**

Notes: (1) The definitions of variables are referred to the notes given in Table 3. (2) '***' signifies significance at the 1% critical level, '**' at the 5% critical level, and '*' at the 10% critical level.

Sources: Table 4.

Let us examine the results of the short run equations. For the air passenger volume equation, GDP and trade are found to have a positive and significant impact on air passenger volume. Ground transport is found to have a supplementary rather than a competitive effect with air transport because the coefficient of ground transport is found to have a positive rather than a negative sign. The policy change after 2002 is found to have a positive and significant effect on air passenger volume. The results on GDP, trade and policy changes are consistent between the short and long run models. Other variables are found to be either insignificant or have the opposite expected effect.

For the air cargo volume short-run model, all the coefficients are found to be insignificant at the 5% critical level and the R^2 is very low. There are two possible explanations for the results. First, air cargo transport does not depend on the short run shocks caused by the explanatory variables. Second, the short-run model may not be a good representation of data without using the error correction mechanism.

Let us now examine the GECM models. First of all, it is important to make sure that the variables specified in the long run equation must have a long-run cointegration relationship. The existence of such a relationship depends on the statistical significance and sign of the coefficients on the lagged dependent variables measured in their levels, that is, 'Air passenger_1' and 'Air cargo_1' in columns 3 and 5 at the lower panel of Table 4. In both equations, the coefficients are found to be significant at the 1% critical level and they both have a negative sign. This means that the ECM has a significant impact in the short-run model, suggesting that the variables in the long-run equation presented in Table 3 are cointegrated. In other words, it can be concluded that the results in Table 3 for the long run equations are not spurious.

In the ECM, further results can be explained as follows. GDP and trade/GDP are found to be significant at the 5% critical level in the air passenger volume equation, confirming the positive impact of economic development and openness on airport development. Population density, ground transport, and employment in the services sector are found to have no significant impact on air passenger volume in this equation. In the air cargo volume equation, GDP, population density and trade/GDP are found to have a significant and positive impact at the 5% or 10% critical level. Ground transport has a significant and negative impact at the 5% critical level, re-affirming the substitution effect that was found in the long run model as well.

Overall, the short-run models and their GECM forms presented in Table 4 provide strong evidence to support the results and conclusions presented in the long-run models in Table 3. Firstly, there exists a long-run cointegration relationship between the dependent and independent variables and most of the seven hypotheses presented in the previous section are supported by the empirical evidence. In particular, market size and the level of economic development represented by GDP, openness represented by trade/GDP ratio, population density, economic structure presented by employment in the services sector, ground transport, location and policy changes are all found to have significant impacts on airport development in China.

6. Conclusions and policy implications

Airport development and air transport in China increased rapidly from 1990. In the 15 years period 1990-2005, air cargo volume increased more than 9-fold and air passenger volume about 8-fold, making China one of the world's fastest growing countries in the civil aviation industry. However, empirical studies on China's airport development are few. This paper is probably the first attempt in the literature to use the most comprehensive and available data at the regional level to quantify the effects of various economic, geographic and policy variables on both the air passenger and cargo volumes during this period of rapid economic growth and airport development in China.

The new contributions of this paper to the existing literature are as follows. First, it uses the most comprehensive airport industry data in China and combines this data with other general economic data to construct an augmented production function, setting an empirical framework to test a few important hypotheses relevant to airport development. Second, it suggests that airport development must be related to the level of economic development, population density, industrial structure, the development of ground transport, policy changes and location. Third, it uses both the long-run and short-run models to study the same issues, making sure that conclusions and results derived from the static long-run models are not spurious and hence can be used to prove the hypotheses.

In both the long and short-run models, it is found that GDP and openness measured by the trade/GDP ratio have a positive and significant impact on air transport (in terms of passenger and cargo volumes) in all model specifications. This implies that economic growth and openness must be the principal drivers of air transportation and airport development. The results are consistent with existing studies that have been conducted in other countries.

In the models, attention is paid to population density and economic structure represented by services sector employment. Although the results are not consistent between the long-run and short-run models, it can be concluded that high population density and high level of industrialization can stimulate the development of the aviation industry. These two variables indicate the so-called agglomerate and industrialization effects on airport development. Understanding such important effects is useful for airport planning and construction.

Ground transport can be substitutes or complements of air transport. The net effects depend on the counteractive forces of these two opposite roles of ground transport. In the long run models, the results show that the substitution effects are more dominant than the complementary effects in both air passenger and cargo transport. However, it is striking to note that the substitution effect in cargo/freight transport is much more significant and sizeable than the substitution effect in air/ground passenger transport. There are two possible explanations for this phenomenon. One is that time-values for people are more important than for freight/cargo. The other is that the adoption of cold storage and the significant improvement on the quality and speed of highways and railways must have increased the competitiveness of ground transport.

In China, the location effect on airport development is important. For example, the west region has a vast territory and is much less populated than the rest of the country. In addition, most of the western provinces have high mountains (Tibet, Yunnan, Guizhou and Qinghai) and large deserts (Xinjiang, Qinghai). As a result, the cost of construction of railways and highways are prohibitively high and the attraction of airport development becomes obvious. Consequently, although the main factors such as GDP and openness have been controlled for, the location effects are found to be highly significant. It implies that given other conditions unchanged, there should be far more incentives to build airports in the western and northeastern regions (and to some extent, the central region) than in the east although the latter is far more advanced, industrialized and densely populated than the rest of the country.

Policy is an important factor and should not be ignored in the planning process. The decentralization and de-regulation policies adopted after 2001 have had some important and interesting effects. For example, this policy is found to have a positive and significant impact on air passenger volume but not on air cargo volume. This does not mean that the new policies are ‘half’ effective as the interpretation on the negative impact on air cargo transport has to be done with caution. In this regard, the policy reforms in the aviation industry after 2001 have been coincided with a fast development of cold storage, high-speed train and the unprecedented construction of motorways in the same period. In less than 15 years of development, the total length of China’s motorways increased from a negligible level to become the second longest motorway network in the world after the US. China aimed to construct 5 vertical (north-south) and 7 horizontal (east-west) pan-country motorway network with a total length of 35,000 km between 1990 and 2020, but this network has been completed 13 years ahead of plan by the end of 2007. The longest north-south motorway from Tongjiang in Heilongjiang to Sanya in Hainan Island has a total length of 5,200 km, which goes through hundreds of long tunnels and tens of rivers and seas. The rapid development of motorways and railways must have a powerful substitution effect on air cargo transport, which is usually far more expensive than ground transport.

The results in this paper have some very important policy implications on airport development in China. First, airport development must be linked to the level of economic development (market size and economic activities). Second, due to the special nature of air transport, the planning for passenger transport and cargo transport must be treated separately. In any airport, the forecast for the demand of these two different transport needs must be based on a comprehensive consideration to include the location factor and the substitution/complementary effects of ground transport. Third, the development of air transport in the west and northeast regions is an important strategy as it becomes an important and effective substitute for ground transport. From the policy point of view, it can also be supported by the country's need to reduce the inter-regional inequality in terms of income and economic growth. The development of air transport should be considered as an important stimulus to promote economic growth in the remote and backward provinces in the west and northeast regions and to reduce the country's overall income and economic inequality spatially.

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