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An Empirical Study on the Indirect Impact of Flight Delay on China's Economy

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Abstract: Due to the influence on the sectors and industries that have strong relationships with the air transportation industry, flight delays have a huge impact on China's economy. In this study, the input–output method and the Ghosh model were used to analyze the indirect economic impacts of flight delays on China's economy. We also constructed simultaneous demand-fare equations to estimate the direct output of the air industry as a result of flight delay control. The final results showed that the total indirect impact of flight delays on China was ¥350.71 billion in 2013, stressing the importance of controlling flight delays. Since delay control not only provides direct benefits to passengers and carriers, but also indirectly contributes to regional economies, the efforts benefit the entire Chinese society. The great investment in flight delay governance should be shared among various producing sectors.

Keywords: flight delay; input–output method; sustainability; indirect impact; China

1. Introduction

Since the late 2000s, flight delay has become an increasingly serious problem and has been spreading in China. Flight on-time performance decreased to 68.33% in 2015 from 81.48% in 2006, according to the Civil Aviation Administration of China (CAAC) reports [1]. FlightStats's June 2015 report also ranked China Eastern Airlines and Air China as the last two carriers out of 50 main international airlines in terms of on-time performance [2]. The resulting inconvenience has successfully drawn the attention of research institutes, mass media, and consensus and relevant government departments, particularly after extensive flight delays because of adverse weather that has occurred more often in China in recent years.

Flight delays not only disturb airline and airport operation, resulting in considerable inconveniences to passengers, but also negatively impact the regional economy because of the strong interactive relationship between air transport and the local economy. Flight delays lead to the increase in the purchase cost of airlines, airports, and other institutions in the air transport industry by other producing sectors. Flight delays also inflate the operating cost of some industries because the procurement and distribution of the products of these industries heavily depend on air transport. For instance, business passenger delay increases administrative costs, leading to an increase in the product's price. This ultimately causes the transaction of related industries to falter. Furthermore, flight delays may constrain the demands of manufacturers from other associated industries, such as tourist services. Consequently, the consumption and requirement of food, accommodation services, retail sales, ground transportation, entertainment, and car rental services will decrease [3]. Combined, these impacts are called the indirect impact of flight delay on the economy. The U.S. Joint Economic Committee appraised the indirect impact of flight delay on the U.S. economy as being equivalent to ¥70.12 billion ($9.6 billion U.S. at the exchange rate on 31 December 2007) in 2007 [4], and the research finding of the National Center of Excellence for Aviation Operations Research (NEXTOR) was ¥29.22 billion ($4 billion U.S. at the exchange rate on 31 December 2007) for 2007 [5].

The economic impact of flight delays in China is also huge and sometimes causes severe reactions. To meet customers' growing needs and simultaneously reduce the extent of flight delay, effective steps to control the delays must be taken. Eleven categories of flight delay reasons exist in Statistical Method of Normal Flight [6] published by CAAC. The annual statistical data of normal flights in the Civil Aviation Statistical Yearbook from 2007 to 2016 show that delayed flights caused by bad weather, inefficient air control and inefficient airline operation accounted for 83.31% of the total delayed flights on average in the years prior to the study. Although not all flight delays can be eliminated, such as those due to serious bad weather, the experiences from the global air transport industry indicate that infrastructure renewal and renovation, such as the expansion of runways and terminals, application of new technology, such as advanced air traffic control technology [5,7], as well as improving operating processes and performance of airlines [8] and airports [9,10] can dramatically decrease the frequency, scope, and extent of flight delays. These measures require significant financial investment. The evaluation of flight delay costs is a method to appraise the potential income of flight delay control, so it can be considered as the investment boundary of flight delay governance.

A few studies focused on domestic Chinese flight delay costs in terms of airlines and passengers. Yefu [11] assessed the average delay time per flight in three scenarios: delay caused by customers, flight waiting on ground and flight placed in a holding pattern. Based these assessments, Yefu estimated that the domestic airlines' delay cost was ¥2.1 billion in 2002. Li et al. [12] found that airlines' delay cost was ¥2.45 billion in 2004, based on Yefu's assessment of delay time per flight, and evaluated passengers' loss as ¥495 million. Several other studies assessed the domestic delay cost for all airlines, based on flight types or in a certain situation, using a previously-introduced method [13–15]. Yuxiu and Jian [8] appraised the total domestic flight delay cost of Chinese airlines based the trans-log cost model. However, no research has focused on the indirect impact of flight delays on China's economy until now. In 2013, we analyzed the economic impact of flight delay. The purpose of this paper was to evaluate the indirect impact of flight delays on China's economy in 2013.

2. Literature Review

Due to the close relationship with other sectors, the economic benefits created by the air transport industry (ATI) are much larger than its own productive effects. Therefore, the development of civil air transportation has become one of the most important driving forces of the local economy and has caught the attention of local government officials, decision makers in the industry and research establishments. Accurately estimating the economic effects is important for developing strategies for ATI. The indirect impact of flight delays on China's economy is the variance in the economic effects of the air transport industry caused by flight delays. Accordingly, understanding the mechanism through which the local economy is impacted by air transport is necessary.

Oxford Economic Forecasting (OEF) constructed an expanded version of the well-established U.K. Industry Model, which explicitly includes the aviation sector to reflect the relationship between ATI and other producing sectors [16]. The OEF's model uses simultaneous equations and has three key factors: employment, capital equipment available, and the sector's productivity. The dynamic relationships among the simultaneous equations and the key findings of the OEF study show that the development of critical sectors in the U.K. economy depends heavily on air transport.

Michael et al. [17] made use of the value-added approach to calculate the direct benefits of ATI caused by accessory services to air transport, and indirect benefits caused by tourism and trade services. They found that the overall economic benefits of the air transportation industry in Hong Kong were ¥79,177.52 million (HK$84,420 million at the exchange rate on 31 December 2003) and accounted for

7.02% of the gross domestic product (GDP) of Hong Kong in 2003. Their results also indicated that the aviation sector had a growing contribution to GDP in Hong Kong.

Kenneth and Samantha [18] constructed a regression model to estimate the influence of international air traffic on U.S. employment and the local economy, with the help of a panel dataset of 41 U.S. Metropolitan Standard Areas samples. European on-plane passengers, European airports, and total enplanements were three independent variables in the complicated regression equation that represented air transportation. In the study of Kenneth and Samantha, they categorized the economic benefits into primary effects, secondary effects, tertiary effects, and perpetuity effects. Mobolaji et al. [19] also built a regression equation with passenger throughput as the dependent variable, and revenues and GDP as the independent variables, to study the relationship between air traffic and the Nigerian economy. They found that the aviation industry creates only 90% of the expected passenger throughput and contributions to the Nigerian GDP.

The input–output (I-O) method is another methodology used in estimating the macroeconomy and analyzing linkage effects. The input–output method was proposed by Wassily Leontief in 1936. It makes use of general equilibrium theory and a chessboard I-O table to conduct empirical research into a quantitative dependence relationship among various economic activities [20]. Many studies used the I-O method to analyze the macroeconomy, including economic benefits, growth ability, and evolutionary features of some industries [21–28]. The transportation industry has strong mutual interdependence with other economic sectors, and this complementary relationship indicates that transportation growth promotes other industries and the entire economy [29]. Hence, the I-O method is suitable for examining the economic effects of transport issues. As a professional institution of the United Nations, the International Civil Aviation Organization (ICAO) recommends using the I-O method to appraise the contribution of air transport to the national economy. With the help of the I-O method, the ICAO indicates that the indirect effects of air transport on local, regional, or national economies include the catalytic and induced demand effects of the output and jobs upon other industries throughout the economy. Catalytic demand effects include off-airport expenditures directly related to the use of air travel and shipment of freight and mail, and induced demand effects are consumer spending from income earned through direct and catalytic economic activities and public expenditures from related tax revenues. In the global economy, the ICAO found that every ¥827.85 ($100 U.S. at the exchange rate on 31 December 2002) of output produced and every 100 jobs generated by air transport triggers an additional demand of ¥2690.51 ($325 U.S. at the exchange rate on 31 December 2002) and 610 jobs in other industries [30]. The U.S. Federal Aviation Administration (FAA) used the adjusted I-O model developed by the U.S. Department of Commerce's Bureau of Economic Analysis, to determine the economic impacts of ATI spending [31]. The FAA's estimated result showed that commercial aviation contributed ¥5310.31 billion ($807.1 billion U.S. at the exchange rate on 31 December 2012) or 5.1% to U.S. GDP in 2012.

In this paper, the ICAO's suggestion is considered, and the I-O method was adopted to evaluate the contribution of flight delay control to China's economy. The remainder of this paper is organized as follows. Section 3 describes the methodology and presents the data. Section 4 discusses the findings from the study. Section 5 draws conclusions and discusses potential future studies in flight delay cost estimating.

3. Methodology

The I-O table is the analytical base of the I-O method. The table reveals the source of inputs and the application of outputs for every producing sector within a certain period. The table can be mainly split into three parts. Table 1 represents the basic I-O table. z_{ij} in Quadrant I shows the service or production provided by one sector to the producing process of other sectors from the transverse direction, and the service or production produced by other sectors that one sector consumes in their producing process from the vertical direction. f_i in Quadrant II reveals the final use of the total outputs of sector i and reveals the application of some goods and services that have permanently or temporarily withdrawn from the current producing cycle. In Quadrant III, v_j shows the value added of formation and composition, which is also called the primary input. Intermediate Use of Quadrant I and Final Use of Quadrant II illustrate the total outputs x_i. The Intermediate Inputs of Quadrant I and Value Added of Quadrant III illustrate the total inputs x_j. x_i is equal to x_j. In the I-O method, quantitative dependence among various sectors can be described through a system of linear equations, and the quantitative dependence is usually studied by several coefficients that are introduced into linear equations.

3.1. Ghosh Model

One of the two approaches to analyzing linkage effects among the producing sectors is examining the forward linkage [32]. Increased output in sector j means that additional amounts of product j are available to be used as inputs in other sectors for their own production. This means increased supplies from sector j (as a seller) are available for the sectors that use good j in their production. Such interconnection is called forward linkage [33]. Forward linkage measures the relationship among various sectors from the supply side. For instance, increased air traffic due to valid flight delay control creates advantages for certain sectors whose operation depends heavily on air transport or uses air service as important intermediate inputs. Similarly, expanding the producing capacity of these sectors stimulates their demand for inputs. This influence can spread to the entire economy through the same mechanism. The Ghosh model [34] is often suggested as being more appropriate for computing forward linkage [33,35,36]. Hence, the Ghosh model was also used in this study to analyze the impact of flight delays on China's economy.

Table 1. Basic input–output table form (¥).

Output / Output		**Intermediate Use**				**Final Use**												
						Total Final Consumption Expenditure					**Gross Capital Formation**							
						Household Consumption Expenditure												
		Sector 1	······	**Sector n**	**Total Intermediate Use**	**Rural Household**	**Urban Household**	**Total**	**Government Consumption Expenditure**	**Total**	**Gross Fixed Capital Formation**	**Changes in Inventories**	**Total**	**Exports**	**Total Final Use**	**Imports**	**Errors**	**Total Output**
Intermediate Inputs	Sector 1																	
	······																	
	Sector n			I z_{ij}							II f_i							x_i
	Total Intermediate Inputs																	
Value Added	Compensation of Employees																	
	Net Taxes on Production																	
	Depreciation of Fixed Assets			III v_j														
	Operating Surplus																	
Total Inputs				x_j														

The Ghosh model reflects the relationship between value added and total outputs by using a direct allocation coefficient (the vector in this paper was defaulted to a column vector, with the superscript $'$ representing the transposed matrix):

$$X' = V'(I - H)^{-1} \tag{1}$$

where X is the column vector of the total output and is specified as $X = (x_1\ x_2\ \cdots\ x_n)'$, V is the column vector of the value added and is specified as $V = (v_1\ v_2\ \cdots\ v_n)'$, I is the identity matrix, and H is frequently called allocation coefficients matrix with the element h_{ij}. We used h_{ij} to represent the allocation coefficient. These h_{ij} coefficients represent the distribution of sector i's outputs across sector j that purchase interindustry inputs from i. The larger the h_{ij}, the greater the direct driving force of sector i on sector j. h_{ij} is calculated as z_{ij}/x_i. We defined:

$$\widetilde{G} = (I - H)^{-1} \tag{2}$$

with the element $\widetilde{g}_{ij}$, where $\widetilde{g}_{ij}$ is called an output-to-primary-input multiplier and represents the augmentation of sector j's total outputs due to a single unit augmentation of the primary input in sector i. The larger the g_{ij}, the greater the complete driving force of sector i on sector j. Row sums of $\widetilde{G}$, $\sum_{j=1}^{n} \widetilde{g}_{ij} = \widetilde{g}_{i1} + \cdots + \widetilde{g}_{in}$, represent the effect on total output throughout all sectors of the economy that would be associated with a single unit change in primary inputs for sector i [36]. These row sums are called supply multipliers. $\widetilde{G}$ is commonly called Ghosh inverse, compared to the usual Leontief inverse. Then, the Ghosh model can be described as:

$$X' = V'\widetilde{G}. \tag{3}$$

In terms of changes in V, the associated output changes would be found as:

$$\Delta X' = \Delta V'\widetilde{G} \tag{4}$$

Equation (4) indicates that we can evaluate the impact of flight delays on China's economy through the changes of value added caused by flight delays and Ghosh inverse. Since only the changes of value added of air transport sector k was measured in this paper, other sectors' output was set to be 0, and $\Delta V'$ was described as $(0, \ldots, \Delta V_k, \ldots, 0)'$. As shown in Quadrant III of Table 1, the four value-added elements are: compensation of employees, depreciation of fixed assets, net taxes on production, and operating surplus. The changes in added value of ATI caused by flight delays are the variation in these four elements.

3.2. Simultaneous Demand and Fare Equations

As the principal part of ATI of China [37], the operating costs and revenue of Chinese airlines are the main operating surplus of ATI, which are influenced by flight delays [4,5,38]. According to Yuxiu and Jian [8], the variation of in the operating costs of Chinese airlines due to flight delay were ¥107.13 billion in 2013. Then, the variation in revenue remains to be determined.

Airline revenue is influenced by the air ticket fare and air passenger demand. These two factors are interactional. Therefore, a simultaneous equation was constructed to examine the relationship between these two elements to calculate the effects of flight delays. Then, the variation in revenue was calculated as the product of fare and the variation in passenger demand, which can be derived from the simultaneous formulas.

Air traffic volume and fare are affected by supply, demand, and air market structure. Supply is determined by passenger demand, input price, route length, and market competition situation [39–42]. Demand is determined by the fare [43], the economy of departure and destination locations, residents' income situation [44], and the route length [45]. Some studies indicated that fare and demand are influenced if a low cost air service exists on the same route or in adjacent cities [42,46–49]. Several newly formed airline companies in China advertise that they provide no-frill air service, but ground infrastructure, rules, regulations, and customer maturity levels in the Chinese air market are not suitable for low cost operations. As a result, the impacts of low cost airlines and no-frill service in the Chinese air market is not currently understood.

Flight delays have become an emerging determinant of passenger demand and fare. Due to the increasing inconvenience due to delays, passenger desire to travel by air will decrease, particularly in the short term because of the ease of acquiring information about delays and carrier performance. Meanwhile, flight delays may increase the input expense and reduce aircraft utilization, and this will affect carriers' operating costs and earnings, and eventually increase the fare in the long term.

Most flight delays occur in busy airports and affect carriers' subsequent operations [38]. Therefore, whether the departure or destination point is at a busy airport was another explanatory factor used in the simultaneous equation.

Hence, adapting Britto's model to the Chinese air market [50], the simultaneous model for a given airline on a given route for a given year is given in Equation (5):

$$\begin{aligned} lnFare &= \varphi_0 + \varphi_1 Delaylag\_SA + \varphi_2 lnPassengers + \varphi_3 lnLength + \varphi_4 lnCompetition + \varphi_5 Busy + \varphi_6 Year_t \\ lnPassengers &= \rho_0 + \rho_1 Delaylag\_A + \rho_2 lnFare + \rho_3 lnIncome + \rho_4 lnGDP + \rho_5 Year_t \end{aligned} \quad (5)$$

where *Fare* is the average ticket price on a given route for a given year, *Passengers* is the number of passengers carried by an airline on a route in a given year, *Length* is the route length, and *Competition* is the market competition situation on a route for a year and is usually measured by the degree of market concentration. *Busy* is a dummy variable set to be 1 if the departure or arrival airport is a busy airport and 0 otherwise. We used the definition of busy airport in the study of Jian et al. [38], where it is defined as an airport with yearly throughput of more than 10 million passengers. *GDP* is the production of the gross domestic product of the departure and arrival cities on a route for a year, *Income* is the population-weighted average income of the departure and arrival cities on a route for a year, and *Year* is a time variable. Our routes panel dataset covered three years from 2011 to 2013. The value of year 2011 was set to be 2011, year 2012 was set to be 2012, and year 2013 was set to be 2013. *Delaylag_SA* and *Delaylag_A* are delay values for an airline on a route for a year and are the two factors we are most concerned about in this paper. The lagged value of delay is used in the model because the behavior of passengers and carriers is always influenced by previous delay situation [50]. *Delaylag_A* is one of the delay types that occur when actual flight arrival times are later than scheduled arrival time. Passenger behavior is mainly affected by *Delaylag_A*, for it is the delay that the passengers think they really experience. To increase the performance appraisal, airlines always add an interval to their optimal flight time to establish the flight schedule. Both the interval added and *Delaylag_A*, which is called *Delaylag_SA* in this article, will increase the airline's operating cost and increase the fare as a result, in the long run.

The Herfindahl–Hirschman index (HHI) was used to evaluate the extent of the air market competition. HHI can be calculated as $HHI = \sum_{i=1}^{n} S_i{}^2$, where Si is the market share of carrier i in a route and n is the numbers of carriers operating on a route. Because of the magnifying function of the quadratic sum in the model, HHI is responsive to non-uniform market share and reveals the influence of the size difference on the degree of market concentration [51–54]. HHI's value is between 0 and 1. The greater the HHI, the closer the market is to being monopolistic and the stronger the pricing situation is for carriers operating on that route. Conversely, with a lower HHI, the air market is more competitive and average fares are usually much lower.

4. Data

The National Bureau of Statistics (NBS) of China began preparing I-O tables in 1987 at five-year intervals. After 2002, the Chinese I-O tables were categorized into 42-sector tables and more detailed

139-sector tables, which include the data from the air transport sector. The latest I-O table including 139 sectors was published in 2012 [55] and it was adopted to 2013 for this article.

The flight delay data was gathered from the Flight Delay Database (FDD) of the Research Center for Environment and Sustainable Development of the China Civil Aviation (RCESD), which is a think tank of CAAC. To construct simultaneous equations of passenger demand and airfare, the Official Aviation Guide (OAG) route data about passengers, fares, and route length for each domestic route for each carrier from 2011 to 2013 was used to calculate HHI for each route. We validated tens of thousands of route data points captured by OAG, and the final sample included 4663 observations broken down into 1144 observations for 2011, 1183 for 2012, and 2336 for 2013. The Statistical Yearbook (SY) of each city annually publishes urban per capita disposable income, permanent resident population, and the GDP of the city. We gathered these data from hundreds of SYs published on the website of each city's statistical bureau. The Production Statistical Communiqué of National Airports, established by the CAAC, reports the passenger throughput of all the airports every year. These data were used to define the busy airports from 2011 to 2013. To be cautious, the 20th percentile of the feasible flight time for a given carrier on a given route for a given year from 2011 to 2013 was used as the optimal flight time [4,56] to compute *Delaylag_SA*. Table 2 provides the descriptive statistics for the variables in the simultaneous equations. Table 3 displays the correlation matrix for the variables. No correlation coefficients exceed 0.5 except *Delaylag_SA* and *Delaylag_A*. The VIF scores are also detected for all independent variables and all values less than 5.0, which indicates that multicollinearity was not serious [57].

Table 2. Descriptive statistics (N = 4663).

Variable	Minimum	Maximim	Mean	SD
Fare (¥)	2.0000	967.0000	145.5514	88.0943
Passengers (No.)	597.0000	1,411,977.0000	72,916.3380	91,544.6550
Delaylag_A (min)	0.0000	382.8900	30.4189	24.6283
Delaylag_SA (min)	5.6000	612.6800	50.8108	26.2665
Length (km)	143.0000	3310.0000	1096.3005	523.5194
Competition	0.1367	1.0000	0.4483	0.2552
Busy	0.0000	1.0000	0.9801	0.1398
Income (¥)	14,692.0924	45,104.9689	33,351.4095	5604.0563
GDP (¥)	7,558,604,002	42,125,430,127,200,000	6,044,669,000,215,000	6,585,541,391,333,720

Table 3. Correlations.

	Year	Fare	Passenger	*Delaylag_A*	*Delaylag_SA*	Length	Competition	Busy	Income	GDP
Year	1									
Fare	−0.131 *	1								
Passenger	0.016	−0.262 *	1							
Delaylag_A	0.086	−0.047	−0.034	1						
Delaylag_SA	0.089	0.063	0.058	0.876 *	1					
Length	0.008	0.487 *	0.114 *	−0.061	0.065	1				
Competition	0.015	−0.135 *	−0.203 *	0.066	0.048	−0.189 *	1			
Busy	−0.01	0.101 *	0.072	0.008	0.055	0.101 *	−0.168 *	1		
Income	0.424 *	0.229 *	0.18 *	0.054	0.149 *	0.093	0.039	0.177	1	
GDP	0.066	0.246 *	0.469 *	−0.044	0.081	0.066	−0.237 *	0.108	0.369	1

Note: * denotes an absolute value of the correlation coefficient ≥0.1.

5. Results

We used the 2012 I-O table for 139 sectors to calculate the supply multiplier of air transport sector. The final result was 3.756134, which indicated that the total output throughout all sectors of China economy would be changed 3.756134 units associated with a single unit change in primary inputs for air transport sector. The output-to-primary-input multipliers of air transport sector are shown from high to low in Table S1. ATI in China strongly supports the development of tertiary industry, especially public management and social organization, business services, wholesale and retail trade, monetary intermediation and other financial services, and education sectors. In addition, modern secondary industry will struggle to develop without the help of ATI, including the building construction, electronic components and parts manufacturing, steel rolling processing manufacturing, and motor vehicles manufacturing. Overall, the data indicate that ATI is a powerful driving force in China's economy, which also means flight delays will take huge impacts to China's economy, especially to the tertiary industry and modern secondary industry.

The two-stage least squares (TSLS) method was used to estimate the simultaneous equations using Eviews 7.2 software (IHS Global Inc., Irvine, CA, USA). The first step was to transfer the structural equation models to reduced-form models. Because a stochastic explanatory variables problem was not present, the reduced-form models were estimated using the Ordinary Least Squares method (OLS). The second step was to replace the dependent variable Y with the estimator $\hat{Y}$, which was determined in the first step. These replaced models can be estimated with OLS. TSLS is the combination of the Indirect Least Square method (ILS) and the Instrumental Variable method (IV). TSLS overcomes the inapplicability of ILS in over identified structural models and the difficulty of choosing instrumental variables in IV [58,59]. Table 4 displays the estimation results. *Income* in the passenger model was removed, as the *t*-statistics value was indistinctive in the first stage of assessment.

Table 4. Fares and passengers simultaneous equations estimates.

		Coefficient	*t*-Statistic
lnFare		——	
	Constant	195.1847 ***	7.991221
	Delaylag_SA	0.000826 **	2.167238
	lnPassengers	0.281956 ***	25.63891
	lnLength	0.464754 ***	22.67013
	lnCompetition	0.087798 ***	4.068926
	Busy	0.269863 ***	3.727018
	Year	−0.09784 ***	−8.05993
lnPassengers		——	
	Constant	−115.768 ***	−3.70762
	Delaylag_A	−0.00039 **	−2.25357
	lnFare	0.410599 ***	24.35224
	lnGDP	0.142424 ***	15.02245
	Year	0.059377 ***	3.825059

Note: *** $p < 0.01$, ** $p < 0.05$.

The signs of the coefficients confirm our expectations. In the fare model, *Passengers*, *Length*, *Competition*, *Busy*, and *Delaylag_SA* were positive. This indicates that these coefficients, in particular delays, have an increasing impact on fares. In contrast, the minus sign of *Year* indicates the downward trend of the average fare price in the Chinese air transportation market, as expected. In the passenger model, the signs mean that economy development has a positive impact on air demand, but delays have a negative impact. It was unexpected that the fare level would have a positive sign in the demand model. This may be due to the rapid growth in demand in the Chinese air market. Despite increasing fare levels, increasing numbers of passengers travel by air for convenience, comfort, and ease, especially in the eastern and southern parts of China where the average income is much higher. In addition, the higher fares do not affect the decisions of passengers to travel by air. However, this trend may change as the Chinese air market matures in the future when more choices for air service are available, particularly when service is provided by low cost carriers.

Delays cause more concern in our study. *Delaylag_A* was −0.00039. This implies the demand will decrease by 0.039% with every additional one minute of flight delay. As determined by the Civil Aviation Statistical Yearbook, the average fare in the domestic air market is ¥789, and there were 327.42 million domestic passengers in 2013. As counted by FDD, average *Delaylag_A* in 2012 was 32.44

min. Then, carrier revenue was estimated to decline by ¥3.27 billion due to flight delays. As has been evaluated by Yuxiu and Jian [8], the increase in the operating costs of Chinese airlines due to flight delays were ¥107.13 billion in 2013. The operating surplus of the air transport sector was assessed as declining by ¥110.40 billion in 2013.

Employee compensation and depreciation of fixed assets are two important airline operating costs. The changes in these two items caused by flight delays can be calculated as the production of the cost share and the variation in airlines operating costs due to flight delays. The financial data in the Civil Aviation Statistical Yearbook (CASY), published by CAAC, issue the income and loss data of airlines, including the cost structure and business tax fee. Through the 2013 CASY financial data [60], we found that human costs accounted for 6.96% of the airline operating costs, asset depreciation accounted for 8.96%. Then, the employee compensation and depreciation of fixed assets were estimated to increase by ¥17.05 billion.

Business tax is the net tax on production that is mainly influenced by flight delays because of the variation in airline income [61], which can be calculated as the production of the average airline business tax rate and the variation in airline revenue caused by flight delay. Through the 2013 CASY financial data [60], we found business tax accounted for 0.68% of the airline operating revenue. Then, the net tax on production was assessed as declining by ¥0.02 billion.

In summary, the value added of the air transport sector in 2013 decreased by ¥93.37 billion due to flight delays. Then, with Equation (4), we calculated the output changes of 139 sectors due to flight delays in 2013. The integral results are shown in Table S1. Then, the impact of flight delays on China's economy in 2013 totaled ¥350.71 billion.

6. Conclusions and Future Research

This paper demonstrates how flight delays affect China's economy. We found that flight delays involved numerous indirect costs on China's economy, and not only on the airlines and passengers as reported by previous studies. Flight delays hamper the development of sectors that considerably use or support the ATI. We also constructed the fare-passenger simultaneous equations to calculate the change in revenue of the ATI caused by flight delays. From the signs of the coefficients, we found that delays have a positive influence on airfare but a negative impact on passenger demand. Hence, our findings indicate that flight delays decrease the competiveness of air transport and hinder the sustainable and healthy growth of the ATI. The impacts of flight delays on air fares and demand also demonstrate that flight delays should not be ignored when managers make decisions about air fares and estimate the air market demand. Our results are a necessary and useful supplement to the assessment of the severity of flight delays in China. These results also evaluate the serious impacts of flight delay control in China from another perspective.

Conversely, the numerous indirect costs mean flight delay control generates huge profits for China's overall economy. Although airlines and passengers are the direct beneficiaries of minimized delays, the other producing sectors and the local economy are also important beneficiaries. We subsequently inferred it is the duty of the ATI operating entities and policymakers to perform flight delay control. This means considerable investment in flight delay control should be shared among the ATI, other producing sectors, and local governments, especially in the cities where busy hub airports are located.

Compared to previous Chinese studies, we expanded the flight delay time frame by using the concept of optimal flight time. Our flight delay not only included the delay that occurs when the actual arrival time is later than the scheduled arrival time, but also the scheduled arrival time that is later than the optimal arrival time as determined by the optimal flight time. This concept helped to completely and accurately assess the severity of flight delays in China.

Only the indirect impacts of flight delays on China's economy were evaluated in this paper. To appraise the complete delay costs, or estimate the limit of investment in delay control, further research must be conducted, including accurately obtaining airline delay costs, more comprehensive passenger loss information, and even evaluating other delay cost perspectives in China's society and economy, including loss of traffic accidents caused by other transportation modes causing passengers disruption due to serious flight delays. Furthermore, to understand the investment direction and the allotment of capital to each area of flight delay control, the causes of flight delay and their respective delay extent should be analyzed in detail. A large amount of work is required in these fields.

Supplementary Materials: The following are available online at www.mdpi.com/2071-1050/10/2/357/s1, Table S1: Output-to-primary-input multipliers of air transport sector and Output changes due to flight delays of 139 sectors in 2013.

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