An Empirical Study of the Impact of the Air Transportation Industry Energy Conservation and Emission Reduction Projects on the Local Economy in China

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Abstract: Green development has been of particular interest to a range of industries worldwide, one of which being the air transportation industry (ATI). The energy conservation and emission reduction (ECER) projects of the ATI have a huge impact on the local economy. In this study, the input-output method was used to analyze the indirect economic impact of the implementation of the ECER projects of the ATI on the local economy of the Beijing-Tianjin-Hebei (BTH) region. We examined the direct benefits, backward spread effects, forward spread effects, and consumption multiplier effects. The final results showed that the comprehensive economic income from 2011–2013 in the BTH region reached RMB 4.74 billion. The results revealed that the ECER projects commissioned by the ATI were worth investing from both the economic and social benefits perspectives. To increase the green development effects and promote the sustainable development of the ATI, the special funds provided by the Civil Aviation Administration of China should be invested intensively in basic green technology research and setting green regulating and governance rules.

Keywords: energy conservation and emission reduction; benefits; air transport; input-output method; green environment; green operation; sustainable development

1. Introduction

A low carbon economy has been evolving to become an emerging and important competitive method worldwide. The International Civil Aviation Organization (ICAO) and European Union (EU), as well as other international or regional organizations have proposed much higher targets for Energy Conservation and Emission Reduction (ECER) in air transport. In these circumstances, green and low carbon development has already been a necessary consequence, and one of the most important developing approaches in the Chinese air transportation industry (ATI). Furthermore, the Civil Aviation Administration of China (CAAC) has also proposed an average goal of an annual 4% reduction of fuel consumption and carbon dioxide release per ton-kilometer during the Chinese 13th Five-Year Term, when compared with the 12th Five-Year Term [1]. In order to fulfill these objectives,
the application of innovative technologies and renewable energies as well as instrument upgrades and
innovative administration policies are the inevitable means. However, global experiences have proved
that the costs of implementing these measures are extremely high, not only in the ATI. Therefore, such
costs and expenses of emission control have obviously been given serious attention by researchers
and practitioners.

With the Global 2100 framework (which was used to assess the overall economic impact of
energy costs increase), Manne and Richels evaluated the influence of price of premium crude oil on
conventionally measured GDP [2]. They found that China was most strongly affected by the higher
energy costs regulated in the international carbon reduction agreements. In order to undertake more
precise calculations with the Computable General Equilibrium model in the future, this research also
carried out some useful attempts including the future variation trends of oil price. Based on their
findings, Manne and Richels proposed the implementation of a carbon tax to reduce the consumption
of carbon-intensive fuel. To assess the control costs that the governments and society should pay to
prevent climate change, Maddison constructed a dynamic non-linear program with the objective of
minimizing the control costs [3]. Emissions reductions and sink enhancement were the two key control
variables in the model, and Maddison put forward several proposals to hold back climate change
based on these findings, for example, afforestation, decreasing emissions, imposing carbon tax, and
removing fossil fuel producer allowances. Fan et al. also used the objective programming approach
to estimate the costs of CO$_2$ emission control in China and indicated that the costs included the
investment in emission reduction and also the losses due to limiting the development of high-emission
sectors [4]. Similarly, several other researchers have assessed the cost of reducing CO$_2$ emissions
in other regions by the same means, for example, the study of Hsu and Chou in Taiwan [5]. The
cost model is another commonly used technique to appraise the expense of emission control. With
the help of a production cost model based on the large panel data of four high-consuming energy
industries, Morgenstern et al. compared the expenditure for the environmental protection of plants
between the reported expense and the actual burden [6]. However, they could not find consistent
results as to whether the reported expenses of the individual plants were overstated or understated
in terms of the actual costs. Such a finding was just another indication of the requirement to assess
the emission control cost/income more precisely. Comparing the whole economic costs of renewable
sources of electricity energy with that of coal-fired power plants, Crane et al. found that the marginal
cost of renewables grew rapidly after Greenhouse Gas emissions were reduced by renewables by
up to 100 million metric tons and the total annual cost of 25% of the Renewable Portfolio Standards
in U.S. would be USD $35 billion [7]. The results also indicated that the substitution of renewables
for coal-fired electricity would prove economical only if the renewables technologies were favorable,
and this also emphasized the significance of the strategies to motivate the development of renewable
technologies (capital expenditure expansion of research and development, for example). Undoubtedly,
the inputs and costs of green and low carbon development cost a large amount in current technical
circumstances all over the world. Unfortunately, the direct economic income of the new technology
will be much lower, even if the effects of ECER were still not stable and obvious in practice. Using the
conservation supply curve and evaluating the technologies cost of conserved energy (CCE), which
includes the investment, operating costs, maintenance costs, and subtracted the cost of saved energy,
Yuan and Lei found that almost half of the technologies used in the iron and steel sector in China
were not cost-effective, and their CCEs were over zero [8].The results of similar researches in the ATI
reach more or less the same outcomes. By calculating the Data Envelopment Analysis value with the
Super Efficiency Data Envelopment Analysis model, Chen and Yu found that a large proportion of
technologies and improvement measures in ECER projects in the ATI of Northern China were not
relatively effective [9]. The non-economic effectiveness or non-economic efficiency in the short-term
suggested the local governments and industry policymakers needed to be more prudent when making
decisions as to whether or not to promote these neo-technologies.
In the ATI of China, aircraft fuel consumption represents 94% of the entire energy expense [10]. The cost of fuel accounts for more than 40% of the total operating costs of the Chinese airline industry [11]. If it is cost effective in accounting, there will be a much larger motive to invest in and promote the energy saving projects. As a result, policy makers and especially the airline managers will pay more attention to aircraft fuel conservation measures such as bio-oil techniques, or the optimal means to cut fuel costs, which was the only deducted income element in Li and Zhu’s CCE model [8]. Many studies have also been devoted to assessing the fuel consumption efficiency of aircrafts [12–15]. The Civil Aviation Administration of China (CAAC) also cares more about the fuel or energy efficiency. During the 12th Five-Year Plan period, the CAAC arranged more than RMB 2 billion to support the airlines, airports, and other institutions to improve energy efficiency and decrease the exhaust gas emissions. However, should the short-term economic benefits of implementing energy saving technologies only include the cost of saved energy? Is such a large amount of funding economically effective? How much in subsidies should the government air transportation departments in China provide when they make investment decisions? The precise and comprehensive understanding and calculation of the economic income of ECER projects is very important when attempting to answer these questions. However, there are few studies in such fields in China. The purpose of this paper is to clearly state and evaluate the comprehensive economic income generated by the investments into ECER by the ATI in China.

2. Literature Review

The economic benefits can be divided into the direct income and the indirect income according to the benefitted range, into the macro income and the micro income according to the benefitted size, and into the short-term income and the long-term income according to the benefitted length of time [16]. To describe the implementation process of the benefits of energy conservation and the emission reduction projects of the ATI, the classification of the direct and indirect income was chosen in this paper.

The ATI is a type of producing sector and can also produce Gross Domestic Product (GDP) (in the input-output tables of China, the components of value added include the Compensation of Employees, the Net Taxes on Production, the Depreciation of Fixed Asset, and the Operating Surplus), which is called the direct income. When the airlines, airports or other utilities of the ATI develop and implement ECER projects, they may hire more employees and invest in some new instruments and equipment. Such projects may also alter the operating expenses (e.g., cutting the cost of fuel) and correspondingly influence income tax. All of these can be treated as the direct income generated by the ECER projects by the ATI.

The ATI is one component in an integrated traffic system and plays a more important role in the development of the local community economy [17,18]. Due to the close relationship with other producing sectors, the benefits created by the ATI are much larger than the income generated on its own. The changed income of the ATI produced by ECER projects will spread to other producing sectors with different correlative patterns. The corresponding influence on the income of other sectors can be called the indirect income of the ECER projects by the ATI. The R&D and implementation of ECER projects by the ATI require a good deal of input in new techniques and facilities as well as a large amount of various kinds of materials and alternative energy sources (e.g., electricity, natural gas, and biofuel). Therefore, the production of the related producing sectors of the ATI will expand and consequently enlarge their demands of the producing inputs. This chain reaction will diffuse to many other industries. Such phenomena can be called the backward spread effects (BSE) of ECER projects by the ATI. Similarly, the ATI is also an important producing unit of other industries and the continuous process of producing in the circulation domain. The implementation of ECER projects can not only decrease emissions, but also help the airlines or airports cut operating costs. Furthermore, it provides the whole industry with an excellent chance to develop new technologies and extend the business and scope of the transportation network. Positive results create advantages that help other producing sectors to expand their production scale, with the capability to transport
more passengers, commodities, and materials. According to the theory of the balance of the national economy, the production expansion of other producing sectors also requires more commodities and materials from their intermediate input supplying sectors. Likewise, the chain reaction will also pervade the whole national economic system. These kinds of benefits are the forward spread effects (FSE) of ECER projects by the ATI. The BSE and the FSE of ECER projects of ATI will also give rise to increased employee salaries due to the enlarged production of the entire producing sector. The increased income of the residents will then generate a new round of consumption and stimulate the production once again. These cyclical effects can be called the consumption multiplier effects (CME). All the BSE, FSE, and CME are the indirect benefits of ECER projects by the ATI.

The value added approach [19], the regression model [20,21], and the simultaneous equations [22] are the most commonly used methods when estimating the influence of air traffic on the local economy. The input-output method (I-O) is another approach that is usually used in many fields to evaluate the macroeconomy such as the economic benefits, the growth ability, and the evolutionary features of some industries [23–27]. For understanding the strong interrelationship with other producing sectors, I-O analysis is suitable for research into the economic effects of transport issues. Hence, the International Civil Aviation Organization (ICAO), which is a specialized UN agency, established by member states in 1944 to manage the administration and governance of the Convention on International Civil Aviation (Chicago Convention), used the I-O method to evaluate the contribution of air transport to the local economy and its findings indicated that every $100 of output produced and every 100 jobs generated by air transport will trigger additional demand of some $325 and 610 jobs in other industries [28]. The Federal Aviation Administration of the U.S. (FAA) also adopted the I-O model to appraise the induced economic impacts of the expenditure by the air transportation industry and their results showed that commercial aviation contributed $807.1 billion or 5.1% to the U.S. GDP in 2012 [29].

Given its strong applicability, the analytical framework and I-O analysis models were adopted in this paper. This study proceeds as follows: Section 3 describes the methodology, Section 4 describes the data and discusses the findings of the study, and Section 5 draws the conclusions and provides some discussion in this area.

3. Methodology

The I-O method was proposed by Leontief in 1936. In the national economic system, the production of each sector needs the outputs from other sectors as the necessary operating resources [30–36]. At the same time, the outputs of each sector are also important operating inputs for other production sectors in the national economic system. The I-O method adopts a chessboard input-output table to reflect the movement processes of the production among various producing sectors from the consumption and distribution aspects [37–43]. Table 1 shows the basic Chinese I-O table form. The I-O table can be mainly split into three parts: The I Quadrant, the II Quadrant, and the III Quadrant. In the transverse direction, the I Quadrant shows the service or production provided by one sector to the other sectors’ producing process. In the vertical direction, the I Quadrant reveals the service or production produced by other sectors that one sector consumes in their producing process. Hence, the I Quadrant is an important information source of the intermediate inputs, the intermediate use, and the I-O relationships between various producing sectors. The II Quadrant reveals the final use of the gross value of production after distribution and redistribution, and contains the final consumption expenditure and the capital formation. The intermediate use in the I Quadrant and the final use in the II Quadrant can provide the allocation and utilization of the total goods and service produced by the whole economic system [44–49]. The III Quadrant shows the formation and composition of the Value Added, which includes the compensation of employees, the net taxes on production, the depreciation of fixed assets, and the operating surplus. Such a constitution can help to calculate the impact of the variation of any industry, including the ATI, to the total macro-economy. The intermediate inputs in the I Quadrant and the value added in the III Quadrant are equal to the total economic inputs and reflect the value composition of the productions or services of each producing sector.
Table 1. Basic input-output table form.

| Input          | Output                          | Sector 1   | Sector 139 | Total Intermediate Use | Value Added | Total Value Added |
|----------------|---------------------------------|------------|------------|-------------------------|-------------|------------------|
| Intermediate  | Inputs                          |            |            | I Quadrant              | Compensation of Employees | II Quadrant              |
|                | Total Intermediate Inputs       |            |            |                         | Net Taxes on Production |                  |
|                | Value Added                     |            |            | I Quadrant              | Depreciation of Fixed Assets |                      |
|                | Total Inputs                    |            |            | II Quadrant             | Operating Surplus           |                  |

| Final Use      | Gross Capital Formation         | Total Final Consumption Expenditure | Gross Fixed Capital Formation | Changes in Inventories | Total Final Use | Imports | Errors | Total (Gross) Output |
|----------------|---------------------------------|------------------------------------|-------------------------------|------------------------|-----------------|---------|--------|---------------------|
|                |                                 | Household Consumption Expenditure  | Total                         | Total                  | Exports         |                      |         |                     |
|                |                                 | Government Consumption Expenditure | Total                         | Total                  | Imports          | Errors      |         |                     |
|                |                                 | Total                               | Total                         | Total                  | Total            |                      |         |                     |

Note: The table format is structured to show the flow of economic activities, where inputs are transformed into outputs through intermediate use and value added, culminating in final use and gross capital formation.
The I-O table has two patterns of manifestation: the physical I-O table and the value I-O table. The value I-O table is widely used because the physical I-O table can only reveal the practical quantitative relationship. The value dependence relationship revealed by the value I-O table can be described through a system of linear equations. Furthermore, there are always several coefficients to be introduced to the system of linear equations to express the techno-economic relationships among various producing sectors and help measure the value quantitative relationships between the general products and the intermediate products or/and the final products. These coefficients were adopted in this study to assess the direct income, BSE, FSE, and CME of the ECER by the ATI to the macroeconomy [17,18,30].

3.1. Direct Income Model

Let \( d_p \) be the direct income of any producing sector \( p \). The direct income model is:

\[
d_p = Z^T \Delta X
\]

where \( \Delta X \) is the output appreciation vector of each producing sector and \( Z^T \) is the value-added coefficient vector. The changed output of the air transportation industry caused by the ECER projects, \( \Delta X_t \), is paid much more attention in this article. Since only air transport sector \( t \) was measured, the other sectors’ output was set to 0, and \( \Delta X \) is described as \((0, \ldots, \Delta X_t, \ldots, 0)^T\). The value-added coefficient of sector \( p \), \( Z_p \), represents the value of GDP generated by a single output of sector \( k \) and can be described as \( z_p / X_p \). \( z_p \) is the added value generated by sector \( p \), including the compensation of laborers, net taxes on production, depreciation of fixed assets, and operating surplus, just the components of each sector in the III Quadrant. \( X_p \) is the output of sector \( p \).

3.2. BSE Model

Let \( b_p \) be the BSE of any producing sector \( k \). The BSE model is:

\[
b_p = Z^T B \Delta X
\]

where \( B \) is the complete consumption coefficient matrix. The complete consumption coefficient is the total consumption—the direct consumption and indirect consumption—of other sectors when producing a single output of sector \( p \). \( B \) can be described as \((I - A)^{-1} - I\), where \( A \) is the direct consumption coefficient matrix, and \( I \) is the identity matrix. The direct consumption coefficient \( a_{ip} \) indicates the amount or value of product \( i \) consumed when manufacturing one unit of product \( p \). \( Z^T B \) is called the BSE multiplier.

3.3. FSE Model

Let \( f_p \) be the FSE of any producing sector \( p \). The BSE model is:

\[
f_p = \Delta X^T Q \times Z^T
\]

where \( Q \) is the complete partition coefficient matrix. The complete partition coefficient shows the share of certain sectors’ production allocated to other sectors through direct and indirect patterns. \( Q \) can be calculated as \((I - H)^{-1} - I\), where \( H \) is the direct partition coefficient matrix. The direct partition coefficient \( h_{pi} \) indicates the amount or value of one unit product \( p \) distributed to manufacture product \( i \). \( Q Z^T \) is called the FSE multiplier.

3.4. CME Model

Keynes proposed the Multiplier Theory based on the Consumption Propensity Principle and derived the quantitative relationship between the gross national income and the investment. That is, the impact of the investment variation on the gross national income is much larger than the investment variation itself. The ratio between the variation of the gross national income and the investment is
called the invest multiplier. The increment of the gross national income generated by the augment of investment also includes the incremental indirect consumption due to such activities. Hence, the invest multiplier is connected with the consumption propensity. According to Keynes’s multiplier principle, the invest multiplier can be described as $1/(1-c)$, where $c$ is the marginal consumption propensity [31]. The function of $c$ is $\sum C / \sum G$, where $\sum C$ is the total consumption of the whole society and $\sum G$ is the total GDP [32]. Let $c_k$ be the CME of any producing sector. Then, the consumption augment generated by the direct income, BSE, and FSE is:

$$c_k = (d_k + b_k + f_k) \frac{c}{1-c}$$

(4)

$c$ is called the consumption multiplier. Summing up all the direct income, BSE, FSE, and CME, the economic impact of ECER projects of the ATI (EIEA) on the total society can be obtained, that is:

$$EIEA = (Z^T \Delta X + Z^T B \Delta X + \Delta X^T \times Q \times Z^T) \times (1 + \frac{c}{1-c})$$

(5)

4. Data and Results

CAAC has arranged special funds annually since 2011 to subsidize and support the entities of ATI to research or/and implement ECER projects. These ECER projects can be categorized into seven groups: energy-saving technology improvement, energy saving by management measures, energy conservation products and green energy application, procurement or/and modification of aviation ground vehicle powered by green energy, air routes optimizing, disposal of airport sewage and waste water and procurement of reclaimed water facilities, and energy statistics and monitoring (There is another category named fundamental and strategic research projects, which generally funds the policies and strategies analysis. Due to the difficulties of measuring the direct income of such research items, this category was not included in our study). The units involved include airlines, airports, air controlling departments, supporting organizations, and other utilities. In 2014, CAAC inspected the execution of ECER in the seven regions (For the managing convenience and efficiency, CAAC established seven branches distributed in seven regions in China, named North China, North East China, North West China, Eastern China, Middle-South China, South West China and Xinjiang) all over China. The Beijing-Tianjin-Hebei region (BTH) is located in North China and has attracted the special attention of the central government of China as an entirety in recent years. The synergetic development of BTH was also highlighted in the report of the 19th CPC National Congress in November 2017. CAAC has also issued The Opinions on Promoting the Coordinated Development of Air Transportation of BTH. We attended the BTH inspecting team and for the data availability, BTH was used as a case in our study to describe the calculating process.

There were 124 projects implemented and funded by CAAC in BTH from 2011 to 2013, and their detailed status is listed in Table 2.

| Year | Airlines Projects Investment (Ten Thousand ¥) | Airports Projects Investment (Ten Thousand ¥) | Other Utilities Projects Investment (Ten Thousand ¥) | Annual New Total Investment * (Ten Thousand ¥) | Annual Newly Total Projects Quantities |
|------|---------------------------------------------|-----------------------------------------------|---------------------------------------------------|---------------------------------------------|----------------------------------------|
| 2011 | 7330                                        | 2439                                          | 0                                                 | 9769                                        | 13                                     |
| 2012 | 22,259                                      | 1017                                          | 0                                                 | 23,276                                      | 55                                     |
| 2013 | 20,148                                      | 6151                                          | 3374                                              | 29,673                                      | 56                                     |

Source: Research Center for Environment and Sustainable Development of China Civil Aviation. * The total investment includes the capital funded by CAAC and the capital invested by every ECER projects implementation subject.

Table 2 shows that the investment on the ECER projects of airlines occupied the major share of the total funds annually and the three-year average from 2011–2013 was 79.52%. This investment
propensity just matched up the ECER features of the ATI, which was that the fuel burned and corresponding exhaust gas discharged by the airlines were the controlling emphasis in the ATI. It also indicated that the investment from the CAAC and the operating entities grew year by year. This suggests that the inputs and the attention on the ECER issues of the ATI have increased over time.

The operating surplus can also be alluded to as the operating results, which are the comparison results between the income and various daily expenditures [33,34]. The ECER projects by the ATI cannot create additional revenue directly. Their main objectives are to increase energy efficiency and save energy consumption. Hence, the income of the projects here are the energy costs saved by the ECER projects of the ATI, e.g., fuel consumption retrenching due to the use of winglets (winglets are devices installed on the wing tip of the aircraft; winglets can help to reduce the induced drag of wings and thus contribute to decrease the fuel consumption) projects. The daily operating costs of the ECER of the ATI not only include the daily instruments maintenance cost, but also the alternative additional energy expenses such as the incremental electric power expenditure because of the ground power unit (GPU) equipment substituted for auxiliary power unit (APU) equipment. Hence, the operating surplus in our study was calculated as the difference between the income and daily operating costs of each project. The main alternation of net taxes on production in the I-O table was due to the implementation of ECER projects by the ATI is the variation of business income tax [35]. According to the data from the Civil Aviation Statistics Yearbook prepared by CAAC, the percentage of income tax to the operating costs of the ATI from 2011 to 2013 was 1.56%, 1.29% and 1.16%, respectively. Additionally, the net taxes on production in our study were the production of the operating surplus and the percentage of income tax to the operating costs. The total capital invested on the ECER projects of the ATI mainly constituted the value of the different kinds of fixed assets such as the Winglets on the aircraft. We assessed the depreciation of these fixed assets according to the assets life time expected by each projects implementation institution with the direct depreciation method. The performance of the ECER projects by the ATI did not need to hire extra employees. Therefore, the compensation of employees was negligible. Then, the changed output of the air transportation industry caused by the ECER projects, \( \Delta X_t \), can be obtained as the summation of the value of the four items above. Table 3 shows the results of the \( \Delta X_t \) of annual new projects. It can be seen in Table 3 that the value of the annual additional \( \Delta X_t \) in 2013 was 1.56 times and 6.18 times as much as the value in 2012 and 2011, respectively. This indicated that the economic outputs of the new ECER projects by the ATI increased as the inputs and the attention on the ECER issues of the ATI were improved.

| Items (units: 10,000 ¥)       | 2011      | 2012      | 2013       |
|-------------------------------|-----------|-----------|------------|
| The operating surplus         | 6849.22   | 28,123.84 | 44,962.85  |
| The net taxes on production   | 108.33    | 366.96    | 525.85     |
| The depreciation of fixed assets | 687.60  | 1873.90   | 1777.23    |
| The compensation of employees | 0.00      | 0.00      | 0.00       |
| Total value of annual additional projects | 7645.14 | 30,364.70 | 47,265.94 |
| Annual accumulated value      | 7645.14   | 38,009.84 | 85,275.78  |

The provincial input-output table has been formally drawn up by the provincial bureau of statistics of various local provincial government of China every five years since 1987. Currently, there are two formats of I-O table, which are the 42-sector table and the 139-sector table. The 42-sector table was expanded to a 139-sector table after 2002 to reflect the input-output relationship in much more detail. The air transportation sector is displayed separately in the 139-sector table. The latest provincial I-O tables including 139 sectors were published in 2012. Due to the objective of this study, the provincial input-output tables of 139 sectors for 2012, published by the local Bureau of Statistics of Beijing, Tianjin, and Hebei, were adopted, which was the closest to 2011 and 2013. Based on the method
and ideas put forward by Jiang [36], we aggregated the data of I-O tables of these three provinces to get the 139-sector I-O table of BTH for 2012. Then we used the 139-sector I-O table of BTH for 2012 to calculate the I-O coefficients.

With the models above described, we calculated the value-added coefficient, the complete consumption coefficient, and the complete partition coefficient of the BTH. The complete results are shown in Appendix A. Table 4 summarizes the top 10 results of the complete consumption coefficient and the complete partition coefficient of the BTH. It was indicated that besides the Air Transport sector itself, the Manufacture of Refined Petroleum Products, Processing of Nuclear Fuel sector and the Extraction of Crude Petroleum and Natural Gas sector were the two sectors that Air transport sector is most reliant upon in BTH. The Manufacture of Other Transport Equipment sector is another sector that provides lots of support to the Air Transport sector in BTH. Such consequences are in line with the actual situation of the ATI. From the overall perspective, the fuel expense and the instruments operating expenditures separately occupied 40.1% and 22.4% of the total operating costs of airlines in 2014 [50]. Table 4 also reveals that the sector of Public Management and Social Organization and the sector of Cargo Handling and Transport Agency were the two sectors that consumed the most ATI products and services in BTH, aside from the Air Transport sector itself. At the same time, the ATI provides strong backing to the development of the tertiary industry in BTH, much like the high-tech industry and the financial industry.

Table 4. Top 10 Complete consumption coefficients and the complete partition coefficient of 139 sectors of BTH.

| Sector                                      | Complete Consumption Coefficient | Sector                                      | Complete Partition Coefficient |
|---------------------------------------------|---------------------------------|---------------------------------------------|--------------------------------|
| Manufacture of Refined Petroleum Products, Processing of Nuclear Fuel | 0.40334971                      | Air Transport                               | 0.196945669                    |
| Extraction of Crude Petroleum and Natural Gas | 0.29464438                      | Public Management and Social Organization   | 0.115877432                    |
| Air Transport                               | 0.19671518                      | Cargo Handling, Transport Agency             | 0.107556231                    |
| Production and Supply of Electricity and Steam | 0.09580717                      | Professional Technique Services             | 0.091913374                    |
| Wholesale and Retail Trade                  | 0.06862760                      | Processing of Steel Rolling Processing      | 0.082559448                    |
| Monetary Intermediation and Other Financial Services | 0.05662297                      | Transport Via Road                          | 0.067977225                    |
| Manufacture of Other Transport Equipment     | 0.05083344                      | Wholesale and Retail Trade                  | 0.067848259                    |
| Processing of Steel Rolling Processing       | 0.04649365                      | Monetary Intermediation and Other Financial Services | 0.066388062                  |
| Cargo Handling, Transport Agency             | 0.04237604                      | Manufacture of Communication Equipment      | 0.059473182                    |
| Mining and Washing of Coal                  | 0.04026107                      | Business Services                           | 0.057342530                    |

Using the data of the annual statistical communiqué of the local economic and social development of Beijing, Tianjin and Hebei, the marginal consumption propensity and the consumption multiplier are calculated to be as showed in Table 5.
Table 5. Marginal consumption propensity and consumption multiplier of BTH from 2011 to 2013.

| Year | Marginal Consumption Propensity | Consumption Multiplier |
|------|---------------------------------|------------------------|
| 2011 | 0.356496                        | 0.5540                 |
| 2012 | 0.362868                        | 0.5695                 |
| 2013 | 0.375767                        | 0.6020                 |

Next, we obtained the EIEA results of the BTH from 2011 to 2013. Table 6 shows the values in detail. This indicated that the EIEA was worth much more than the capital invested on the ECER projects of the ATI. The total EIEA of these three years was ¥3.52 billion and the comprehensive economic income of these three years, which is the sum of the EIEA and the accumulated operating surplus, reached ¥4.74 billion and was 7.56 times as much as the total funds and capital invested. The results are clear evidence that the ECER projects of the ATI not only generate emissions reduction and promote the green development of the whole industry, but contributed much more to the national economy due to the operating expense saved due to the drop in the energy and fuel consumption.

Table 6. The economic impact of ECER projects of by the ATI and comprehensive income of ECER projects of the ATI in BTH from 2011 to 2013 (ten thousand ¥).

| Years              | 2011      | 2012      | 2013      |
|--------------------|-----------|-----------|-----------|
| The direct income  | 2460.23   | 12,231.67 | 27,441.98 |
| BSE                | 5187.33   | 25,790.18 | 57,860.74 |
| FSE                | 5289.02   | 26,295.74 | 58,994.99 |
| CME                | 7166.74   | 36,630.97 | 86,862.21 |
| EIEA               | 20,103.32 | 100,948.56| 231,159.92|
| The annual accumulated operating surplus | 6849.22 | 34,973.06 | 79,935.91 |
| The annual comprehensive income | 26,952.54 | 135,921.62 | 311,095.83 |

5. Discussion

It can be seen that in order to boost the yield of ECER projects, improving the direct operating surplus will be the key point. That is, strengthening the energy-saving potential and then cutting the operating energy consumption expenses of the projects’ executing units. It is precisely due to such effects that airlines have a greater interest in executing projects such as the modification of winglets or aeromotors to cut down on their fuel costs. The total investment of BTH from 2011 to 2013 on such equipment reconstruction items was ¥3.72 billion, which occupied 59.24% of the overall capital and funds. It should also be noted that the funds provided by CAAC on these types of instrument modification projects totaled ¥1.14 billion, which was 60.75% of the general CAAC finance on ECER projects in the BTH region. However, the recent practice and global revolution tendency of ECER showed that the innovation of fundamental technology (e.g., R&D on biofuel and advanced materials) and green development rules, policies and strategies were exactly the most pivotal solutions to increase the prospective ECER efficiency, especially in China. Such kinds of studies and actions cost a huge amount of funds and human capital, aside from the very long preparation and research time. Furthermore, the direct economic benefits usually do not appear in the short-term or the net value is negative, sometimes the R&D of such projects even falls through to nothing. They contain more characteristics of public goods and non-profits. There is no business willing to invest in economically unviable projects. In the modern national governance system, it is the duty of the governmental institutions, like the CAAC, to perform the function of regulating, governance, and providing public services. It needs to let the market take the decisive role in resource allocation, that is, the airlines themselves still have great desire to invest in and execute projects that can produce valuable returns even without the support of the CAAC. Hence, we suggest that the special funds of the CAAC in the green development field are better spent to intensively subsidize the areas of basic green technology.
research, setting green standards and other crucial policies and strategies (e.g., constructing the market for trading carbon emissions).

6. Conclusions and Future Research

We measured the comprehensive economic contribution of the ECER projects by the ATI in BTH with the I-O method. The results showed that such capital and funds invested on these projects produced more direct and indirect income. Hence, the ECER projects are worth investing in from the perspectives of both the economic and social benefits. The overall gains assessed could be one of the judgement foundations for governmental departments like CAAC and other entities in the ATI when making investment decisions regarding ECER projects.

A uniform carbon emissions trade scheme (ETS) has not been established in China up until now. At present, there are only some experimental markets in several provinces. Therefore, the operating surplus in this study was only calculated as the difference between the energy costs saved and the daily operating costs of each project. Once a formal Chinese ETS has been set up and all market entities are participants, the operating surplus should extend to cover such income and loss. Meanwhile, the impacts of Chinese ETS to the green development of ATI are also worthy of a large amount of work.

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## Appendix A

### Table A1. Value added coefficient, complete consumption coefficient and complete partition coefficient of 139 sectors of BTH.

| Sector                                      | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient | Sector                                      | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient |
|----------------------------------------------|-------------------------|----------------------------------|--------------------------------|----------------------------------------------|-------------------------|----------------------------------|---------------------------------|
| Farming                                      | 0.65809490             | 0.00948396                       | 0.00827421                    | Manufacture of Machinery for Mining, Metallurgy and Construction | 0.33121757             | 0.00793551                       | 0.00658125                      |
| Forestry                                     | 0.66232362             | 0.00160568                       | 0.00036001                    | Manufacture of Machinery for Chemical Industry, Timber and Nonmetal Processing | 0.29064418             | 0.00164671                       | 0.00173513                      |
| Animal Production                            | 0.45784935             | 0.00414203                       | 0.00567587                    | Manufacture of Machinery for Agriculture, Forestry, Animal Production and Fishery | 0.23530930             | 0.00011866                       | 0.00166339                      |
| Fishery                                      | 0.55240879             | 0.00177300                       | 0.00103603                    | Manufacture of Other Special Purpose Machinery | 0.32346857             | 0.01044556                       | 0.01138952                      |
| Support Services to Farming, Forestry, Animal Production and Fishery | 0.42785223           | 0.00054121                       | 0.00274617                    | Manufacture of Motor Vehicles, Except Parts and Accessories for Motor Vehicles | 0.23432010             | 0.00503332                       | 0.02322162                      |
| Mining and Washing of Coal                   | 0.48668547             | 0.04026107                       | 0.01592184                    | Manufacture of Parts and Accessories for Motor Vehicles | 0.22017552             | 0.00688963                       | 0.01486032                      |
| Extraction of Crude Petroleum and Natural Gas | 0.67784955           | 0.29464438                       | 0.00417251                    | Manufacture of Railway Transport Equipment | 0.27868824             | 0.00191602                       | 0.00245919                      |
| Mining of Ferrous Metal Ores                 | 0.27078909             | 0.02206412                       | 0.03042053                    | Manufacture of Boats and Ships and Floating Devices | 0.28240476             | 0.00066540                       | 0.00066575                      |
| Mining of Non-Ferrous Metal Ores             | 0.48923841             | 0.00136688                       | 0.00039493                    | Manufacture of Other Transport Equipment | 0.31015770             | 0.05083344                       | 0.00689735                      |
| Mining and Quarrying of Nonmetallic Mineral | 0.32712220             | 0.00334709                       | 0.00181540                    | Manufacture of Generators and Eclectic Motors | 0.19549452             | 0.00187505                       | 0.00298272                      |
| Mining Support Activities and Other Mining and Quarrying n.e.c. | 0.24341047           | 0.00123681                       | 0.00420443                    | Manufacture of Equipments for Power Transmission and Distribution and Control | 0.16727462             | 0.00782830                       | 0.00931105                      |
| Manufacture of Grain Mill Products           | 0.13832790             | 0.00111169                       | 0.00121742                    | Manufacture of Wire, Cable, Optical Cable and Electrical Goods | 0.20990082             | 0.00735762                       | 0.00767773                      |
| Sector                                      | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient | Sector                                      | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient |
|---------------------------------------------|-------------------------|----------------------------------|--------------------------------|---------------------------------------------|-------------------------|----------------------------------|--------------------------------|
| Manufacture of Prepared Animal Feeds        | 0.15576646              | 0.00142819                       | 0.00438317                     | Manufacture of Batteries                    | 0.18733435              | 0.00096873                       | 0.00770118                     |
| Manufacture of Crude and Refined Oils from Vegetable | 0.16310035              | 0.00106132                       | 0.00370546                     | Manufacture of Household Appliances         | 0.20539426              | 0.00033581                       | 0.00315946                     |
| Manufacture of Sugar                        | 0.29309175              | 0.00061953                       | 0.0008414                      | Manufacture of Other Electrical Machinery and Equipment | 0.30958159              | 0.00148781                       | 0.00228048                     |
| Slaughtering and Processing of Meat         | 0.18278184              | 0.00251932                       | 0.00252465                     | Manufacture of Computer                     | 0.12192421              | 0.00631335                       | 0.00453914                     |
| Processing of Aquatic Products              | 0.23232448              | 0.00086776                       | 0.0018777                      | Manufacture of Communication Equipment      | 0.12432004              | 0.00158658                       | 0.05947318                     |
| Processing of Other Foods                   | 0.21776476              | 0.00170671                       | 0.00363674                     | Manufacture of Broadcasting, Television Equipment of Radar and Related Equipment | 0.33123257              | 0.00054312                       | 0.00111618                     |
| Manufacture of Convenience Food Products    | 0.34504947              | 0.00063443                       | 0.00256413                     | Manufacture of Audiovisual Apparatus         | 0.18389076              | 0.00145535                       | 0.00323154                     |
| Manufacture of Milk and Dairy Products       | 0.19887917              | 0.00121440                       | 0.00252478                     | Manufacture of Electronic Components and Parts | 0.20156038              | 0.00127918                       | 0.04235060                     |
| Manufacture of Flavoring and Ferment Products | 0.27199137              | 0.00089935                       | 0.00053458                     | Manufacture of Other Electronic Equipment | 0.28263573              | 0.00020301                       | 0.01121072                     |
| Manufacture of Other Food Products n.e.c.* | 0.29356508              | 0.00365770                       | 0.00766440                     | Manufacture of Measuring Instruments and Meters | 0.30774442              | 0.00422400                       | 0.00854029                     |
| Manufacture of Alcohol and Alcoholic Beverages | 0.34193329              | 0.00422413                       | 0.00188450                     | Other Manufacture                            | 0.23311783              | 0.00256814                       | 0.00320148                     |
| Manufacture of Soft Drinks and Refined Tea Products | 0.27025151              | 0.00696313                       | 0.0038421                      | Comprehensive Utilization of Waste Resources | 0.42887971              | 0.00501575                       | 0.0023219                      |
| Manufacture of Tobacco Products             | 0.76213530              | 0.00008918                       | 0.00040446                     | Repair of Fabricated Metal Products, Machinery and Equipment | 0.40629456              | 0.00471970                       | 0.00142737                     |
| Sector                                                                 | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient | Sector                                                                 | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient |
|-----------------------------------------------------------------------|--------------------------|---------------------------------|--------------------------------|-----------------------------------------------------------------------|--------------------------|---------------------------------|--------------------------------|
| Spinning, Weaving and Finishing of Cotton and Chemical Fibers         | 0.22435333              | 0.00357610                      | 0.00916149                     | Production and Supply of Electricity and Steam                        | 0.19043911              | 0.09580717                      | 0.02982044                     |
| Spinning, Weaving and Finishing of Wool                               | 0.23845787              | 0.00033333                      | 0.00111817                     | Production and Distribution of Gas                                     | 0.27963437              | 0.00357168                      | 0.00123536                     |
| Spinning, Weaving and Finishing of Bast and Silk Fibers               | 0.25095633              | 0.00011531                      | 0.00004119                     | Production and Distribution of Water                                  | 0.29976591              | 0.00282607                      | 0.00150234                     |
| Manufacture of Knitted and Crocheted Fabrics and Articles, Except Apparel | 0.23668137              | 0.00354964                      | 0.00051150                     | Construction of Buildings                                             | 0.23044404              | 0.00455016                      | 0.005605056                    |
| Manufacture of Made up Textile Articles, Except Apparel               | 0.29401192              | 0.00344994                      | 0.00181027                     | Civil Engineering                                                     | 0.18669942              | 0.0000109                       | 0.01919112                     |
| Manufacture of Textile Wearing Apparel                                | 0.31842498              | 0.00313491                      | 0.00715224                     | Construction Installation Activities                                   | 0.41447198              | 0.0003788                       | 0.00456523                     |
| Manufacture of Leather, Fur, Feather and Its Products                | 0.27903598              | 0.00065630                      | 0.00600132                     | Construction Completion and Finishing, Other Construction Activities | 0.31615894              | 0.01015577                      | 0.00270952                     |
| Manufacture of Footwear                                               | 0.24615226              | 0.00002430                      | 0.00048226                     | Wholesale and Retail Trade                                            | 0.73610322              | 0.06862760                      | 0.06784826                     |
| Processing of Timbers and Manufacture of Products of Wood, Bamboo, Rattan, Palm and Straw | 0.24427915              | 0.00326586                      | 0.00147456                     | Transport Via Railway                                                 | 0.47313872              | 0.01173610                      | 0.00603715                     |
| Manufacture of Furniture                                              | 0.25394624              | 0.00046908                      | 0.00251287                     | Transport Via Road                                                    | 0.46357428              | 0.02663423                      | 0.06797723                     |
| Manufacture of Paper and Paper Products                               | 0.22719333              | 0.00856405                      | 0.00622567                     | Water Transport                                                       | 0.19422865              | 0.01491260                      | 0.03464911                     |
| Printing and Reproduction of Recording Media                          | 0.32160578              | 0.00447675                      | 0.00289300                     | Air Transport                                                        | 0.32180275              | 0.19671518                      | 0.19694567                     |
**Table A1. Cont.**

| Sector                                                                 | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient | Sector                                                                 | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient |
|------------------------------------------------------------------------|--------------------------|---------------------------------|-------------------------------|------------------------------------------------------------------------|--------------------------|---------------------------------|-------------------------------|
| Manufacture of Stationeries, Musical Instruments, Products of Arts and Crafts, Sports Goods, Games and Toys | 0.31053965               | 0.00213193                      | 0.00276225                    | Transport Via Pipeline                                                 | 0.59513156              | 0.01570324                      | 0.00086432                    |
| Manufacture of Refined Petroleum Products, Processing of Nuclear Fuel | 0.12580389               | 0.40334971                      | 0.01314310                    | Cargo Handling, Transport Agency                                       | 0.23809387              | 0.04237604                      | 0.10755623                    |
| Manufacture of Coke Products                                          | 0.15422770               | 0.00556278                      | 0.00822360                    | Storage                                                               | 0.22669326              | 0.00112504                      | 0.01538479                    |
| Manufacture of Basic Chemicals                                         | 0.21514787               | 0.01209001                      | 0.01071987                    | Post                                                                  | 0.47298839              | 0.00056459                      | 0.02399714                    |
| Manufacture of Fertilizers                                            | 0.20867100               | 0.00143761                      | 0.00170702                    | Accommodation                                                          | 0.38835318              | 0.00676270                      | 0.00761059                    |
| Manufacture of Pesticides                                             | 0.12732769               | 0.00041968                      | 0.00137720                    | Food and Beverage Services                                            | 0.39619440              | 0.02105532                      | 0.01085963                    |
| Manufacture of Paints, Printing Inks, Pigments and Similar Products    | 0.24636065               | 0.00294550                      | 0.00401435                    | Telecommunication and Other Information Transmission Services          | 0.53681145              | 0.01261370                      | 0.02396582                    |
| Manufacture of Synthetic Materials                                    | 0.28015570               | 0.00618445                      | 0.00588272                    | Software and Information Technology Services                           | 0.31948691              | 0.00165269                      | 0.04957960                    |
| Manufacture of Special Chemical Products                              | 0.22699814               | 0.01156736                      | 0.00535333                    | Monetary Intermediation and Other Financial Services                  | 0.67209964              | 0.05662297                      | 0.06638806                    |
| Manufacture of Daily-use Chemical Products                             | 0.30941548               | 0.00128641                      | 0.00187901                    | Capital Market Services                                               | 0.76535576              | 0.00895409                      | 0.00041444                    |
| Manufacture of Pharmaceutical Products                                | 0.27082951               | 0.00064797                      | 0.02104495                    | Insurance                                                             | 0.39547371              | 0.00632375                      | 0.01038181                    |
| Manufacture of Chemical Fibers                                        | 0.18204210               | 0.00102124                      | 0.00125299                    | Real Estate                                                           | 0.71790970              | 0.02130404                      | 0.03462631                    |
| Manufacture of Rubber Products                                        | 0.25239312               | 0.00363817                      | 0.00531817                    | Renting and Leasing                                                   | 0.56215994              | 0.00748130                      | 0.00341211                    |
| Sector                                      | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient | Sector                                      | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient |
|---------------------------------------------|-------------------------|----------------------------------|--------------------------------|---------------------------------------------|-------------------------|----------------------------------|---------------------------------|
| Manufacture of Plastic Products             | 0.29046660              | 0.00908359                      | 0.00917636                    | Business Services                          | 0.36904634              | 0.02502596                      | 0.05734253                      |
| Manufacture of Cement, Lime and Plaster     | 0.27823446              | 0.00157101                      | 0.00422344                    | Research and Experimental Development       | 0.35856302              | 0.00128940                      | 0.02532175                      |
| Manufacture of Products of Plaster and Cement and Similar Products | 0.22342353              | 0.00100909                      | 0.00364078                    | Professional Technique Services             | 0.35692944              | 0.00481100                      | 0.09191337                      |
| Manufacture of Brick, Stone and Other Building Materials | 0.23839244              | 0.00307113                      | 0.00251076                    | Technique Promotion and Application Services | 0.30464171              | 0.00549408                      | 0.01778830                      |
| Manufacture of Glass and Glass Products      | 0.24724381              | 0.00261151                      | 0.00306518                    | Management of Water Conservancy             | 0.70200573              | 0.00013141                      | 0.00102277                      |
| Manufacture of Cematic and Porcelain Products | 0.3653512               | 0.00030761                      | 0.00056562                    | Ecological Protection and Environmental Control | 0.54614595              | 0.00079457                      | 0.00157587                      |
| Manufacture of Refractory Products           | 0.23742876              | 0.00029001                      | 0.00139037                    | Management of Public Facilities             | 0.40298102              | 0.00026765                      | 0.00280499                      |
| Manufacture of Products of Graphite and Other Nonmetallic Minerals | 0.28145882              | 0.00088691                      | 0.00150467                    | Services to Households                       | 0.51721516              | 0.00059880                      | 0.01123691                      |
| Manufacture and Casting of Basic Iron and Steel | 0.20831107              | 0.01757995                      | 0.02450266                    | Repair of Motor Vehicles, Electronic Products and Household Goods and Other Services | 0.37892044              | 0.01380824                      | 0.02343402                      |
| Processing of Steel Rolling Processing       | 0.18639454              | 0.04649365                      | 0.08259455                    | Education                                    | 0.58973109              | 0.0079619                       | 0.04671477                      |
| Manufacture of Ferroalloy                    | 0.15375489              | 0.00139675                      | 0.00040777                    | HealthCare                                   | 0.41398704              | 0.00012923                      | 0.01972915                      |
| Manufacture and Casting of Non-Ferrous Metals and Related Alloys | 0.22072408              | 0.01302412                      | 0.00274603                    | Social Work Activities                       | 0.73139023              | 0.00007183                      | 0.00035766                      |
| Processing of Non-Ferrous Metals Rolling     | 0.18359761              | 0.01005773                      | 0.00587403                    | Journalism and Publishing                    | 0.39946103              | 0.00103748                      | 0.0067849                       |
| Sector                                               | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient | Sector                                               | Value Added Coefficient | Complete Consumption Coefficient | Complete Partition Coefficient |
|------------------------------------------------------|--------------------------|-----------------------------------|--------------------------------|------------------------------------------------------|--------------------------|-----------------------------------|--------------------------------|
| Manufacture of Fabricated Metal Products, Except Machinery and Equipment | 0.21077530               | 0.02066896                        | 0.02476300                     | Radio, Televisions, Movies and Audio-Video Recording Activities | 0.40828552               | 0.00150128                        | 0.01213762                      |
| Manufacture of Boiler and Prime Mover                | 0.21864505               | 0.00191237                        | 0.00247806                     | Cultural, Art and Entertainment Activities           | 0.60462902               | 0.00013894                        | 0.00271520                      |
| Manufacture of Metalworking Machinery                | 0.21693402               | 0.00104880                        | 0.00259596                     | Sports Activities                                    | 0.47942641               | 0.00001831                        | 0.00415866                      |
| Manufacture of Lifting and Handling Equipment        | 0.27426288               | 0.0027885                        | 0.00472780                     | Amusement and Recreation Activities                  | 0.48539412               | 0.00078213                        | 0.00131621                      |
| Manufacture of Pump, Valve, Compressor and Similar Machinery | 0.26708758               | 0.00173390                        | 0.00732001                     | Social Security                                      | 0.74156563               | 0.00000286                        | 0.00300117                      |
| Manufacture of Movie, Office Machinery and Equipment, of Projector and Camera | 0.14748173               | 0.00068815                        | 0.00247928                     | Public Management and Social Organization            | 0.55795782               | 0.00195229                        | 0.11587743                      |
| Manufacture of Other General-Purpose Machinery       | 0.24428034               | 0.01351929                        | 0.01113402                     | ——                                                   | ——                       | ——                               | ——                            |
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