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Assessment of carbon emission costs for air cargo transportation

Ching-Cheng Chao *

Department of Shipping and Transportation Management, National Kaohsiung Marine University, 142 Hai-Jhuan Road, Nan-Tzu, Kaohsiung 811, Taiwan, ROC

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ABSTRACT

This study presents a set of models that calculate carbon emissions in individual phases of flight during air cargo transportation, investigates resultant carbon footprints by aircraft type and flight route, and estimates increases in transportation costs for airlines due to carbon taxes imposed by the EU ETS. The estimated results provide useful references for airlines in aircraft assignment on different routes and in aircraft selection for new purchases. Validation of the model is conducted by simulating the potential impact of the implementation of the EU ETS on costs of air cargo transportation for six routes and six types of aircraft. Results show that the impact may be subject to various factors including unit carbon emissions per aircraft, aviation emission allowances per airline, and carbon trading prices; and that increases in costs of air cargo transportation range from 0% to 5.27% per aircraft per route. Therefore, the implementation of the EU ETS may encourage airlines to cut down their operating costs by reducing their carbon emissions, thereby ameliorating greenhouse gas pollution caused by air cargo transportation.

Introduction

All countries that ratified the United Nations Framework Convention on Climate Change are required to reach their emission reduction targets. Flexible mechanisms, including emissions trading, are built into the Kyoto Protocol to help participating industrial countries adjust their internal costs for carbon emission reductions in order to fulfill their commitments. Moreover, these mechanisms serve to enhance the abilities and capacities of the parties involved. In 2005, the European Union (EU) implemented an emissions trading scheme (ETS) for certain industries and installations to partially fulfill their obligations under the Kyoto Protocol, thereby reducing greenhouse gas (GHG) emissions (European Union, 2003). The EU ETS is in its third trading period, which will continue through 2020. Therefore, aviation is now exposed to the risk of fluctuating CO_2 prices.

Aviation CO_2 emissions account for a small percentage of the global average (approximately 2.5% in 2007 (International Transport Forum (ITF), 2010)), but there are currently no global legally binding policies aiming for emission reductions, and with the growth of the industry projected to increase by 4.8% per year beyond 2030 (ICAO, 2010), aviation CO_2 emissions will continue to rise. With rapid technological development and the advent of new electronic products in the market, the past decades have witnessed tremendous growth in international air cargo transportation across the closely linked global supply chain. According to the Boeing World Air Cargo Forecast (Boeing, 2012), global air cargo traffic will expand at an average annual rate of 5.2% in the next 20 years.

* Tel.: +886 7 3617141x3156; fax: +886 7 3647046.
E-mail address: chaocc@webmail.nkmu.edu.tw

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In recent years, green supply chains have attracted global attention and many airlines are striving to reduce carbon footprints generated during the course of air transportation. The International Organization for Standardization (ISO) provides in ISO/WD.2 14067-1 a production system model that assesses the carbon footprint of a product during the product's entire lifecycle. Miettinen and Hämäläinen's (1997) lifecycle assessment (LCA) assesses processes or related activities during a product's entire lifecycle that reflect different stages of the cycle (i.e., material acquisition, manufacturing, use, and ultimate disposal). Carbon footprints are often used for measuring environmental sustainability and can reflect direct and indirect GHG emissions resulting from products, processes, or systems. GHG emissions arising from transportation of materials or products, including land, air, water, railway, or other means, across the global logistics supply chain should be included in the assessment of GHG emissions during product lifecycles.

Scheelhaase et al. (2010) provided an overview of recent political developments in the EU, as well as the International Civil Aviation Organization (ICAO), regarding emissions trading and aviation. They further analyzed how the EU directive on the inclusion of international aviation in the EU ETS affects competition between European and non-European airlines. Anger and Kohler (2010) reviewed the available impact assessments of the proposed emissions trading scheme for airlines published between 2005 and 2009. Overall, the effects were found to be small. Mayor and Tol (2010) used a model comprised of numbers and flows of international and domestic tourists to investigate the effect of various climate policy instruments implemented in Europe on arrivals and emissions for the countries concerned. They found that these schemes did not fulfill their desired effects.

Malina et al. (2012) estimated economic impacts on US airlines that may arise from the inclusion of aviation in the EU ETS from 2012 to 2020. They found that the EU ETS would have only a small impact on US airlines and emissions, and aviation operations would continue to grow. Tsai et al. (2012) presented a mixed activity-based cost decision model for green airline fleet planning under the constraints of the EU ETS, in which a modified product-mix decision model was incorporated for calculating total operating costs of individual flights. Girardet and Spinler (2013) developed a fuel surcharge model for air transport in relation to kerosene and CO_2. The calculation model included price increase-induced demand reactions, which in turn may affect profitability.

In the past, estimates of aircraft GHG emissions per flight relied mostly on general estimation (ICAO, 2010). However, aircraft fuel consumption and carbon emission factors vary in different phases of flight. In view of this, the present study develops a set of models that calculate carbon emissions from freighter aircraft in individual phases of flight by aircraft type, flight distance, and airport location to investigate the resultant carbon footprints and to estimate increases in transportation costs for airlines due to carbon taxes imposed by the EU ETS. To validate the proposed models, a case study was conducted on six routes and six types of aircraft operated by China Airlines (CAL)[1] and EVA Airways (EVA).[2] Findings of this study can serve as references for airline companies on aircraft assignment and aircraft selection in new purchases, as well as for companies to determine the carbon footprint of their products during the air transport phase and in choosing low-carbon air cargo carriers.

The remainder of the paper is organized as follows: Section 'Model formulation' details the model formulation. A case study is provided in Section 'Case study' to illustrate and validate the application of the developed models. Finally, Section 'Conclusions and suggestions' contains the conclusions of this study and suggestions for future research.

Model formulation

Aircraft operations are usually divided into two main parts: landing/take-off (LTO) cycle and cruise. As defined by the ICAO (1993), the LTO cycle includes all activities near the airport that take place at altitudes below 3000 feet. Cruise is defined as all activities that take place at altitudes above 3000 feet. Cruise includes climb from the end of climb-out in the LTO cycle to the cruise altitude, cruise, and descent from cruise altitude to the start of landing operations (see Fig. 1). Hence, the calculation of aircraft carbon emissions in this study is divided into two phases: LTO cycle and cruise.

Models for estimating total GHG emissions from individual freighter aircraft

According to IPCC 2006 Guidelines for National Greenhouse Gas Inventories, aviation GHG emissions are calculated according to fuel consumption and GHG emission factors. However, aircraft fuel consumption and carbon emission factors vary in different phases of flight. To accurately assess GHG emissions in individual phases of flight, this study develops a set of models with reference to methodologies for estimating emissions of aircraft pollutants proposed by Kurniawan and Khardi (2011) and Loo et al. (2014). These models calculate carbon emissions from freighter aircraft in individual phases of flight by aircraft type, flight distance, and airport location. Assessment starts by dividing the flight of an aircraft into the abovementioned phases: LTO cycle and cruise. Let E_{ij}^{od} stand for the total emissions of GHG *j* by aircraft type *i* from departure airport *o* to destination airport *d*, then E_{ij}^{od} can be formulated as:

$$E_{ij}^{od} = LTO_{ij}^{od} + CR_{ij}^{od} \tag{1}$$

[1] China Airlines, the largest airline in Taiwan and a member of SkyTeam, was founded in 1959. It operates flights to 113 destinations in 29 countries. Its fleet is comprised of 56 Boeing and Airbus passenger aircraft and 21 cargo aircraft (http://www.china-airlines.com.)

[2] EVA Airways, the second largest Taiwanese airline and a member of Star Alliance, was founded in 1989. Its route network covers 71 destinations spread over Europe, North America, Asia, and Oceania. Its fleet is comprised of 48 Boeing and Airbus passenger aircraft and 13 cargo aircraft (http://www.evaair.com.)