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Original Article

A Study on Airlines Network Changes by Emission Charges

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배출가스 부과금에 따른 항공사 네트워크의 변화에 관한 연구

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ABSTRACT

Air travel has become an essential part of the global society and its sustainable development is expected. Airlines profit structure and network operation will be influenced by internalization of external costs like emission charge. This additional cost of the airlines will be directly pose air ticket fare increase and demand of air passenger will be decreased. EU-ETS is a part of environmental binding to airlines fly to EU territory airports. This study analyzes the impact of emission charges by application of EU-ETS on airlines network change. For long-term forecast, a reliable estimation of the future price of carbon dioxide (CO2) will be used

Key Words : Emission charges(배기가스부담금), EU-ETS(유럽연합-ETS), Airlines Network (항공사 네트워), long-term forecast(장기전망)

Ⅰ. Introduction

Civil aviation has been growing for last several decades at higher rate than average economic growth and this trend will last in future as air travel has become an essential part of the global society. However, it couldn’t be avoided the impact of aviation on the global climate change because aviation is also a source of greenhouse gases. Airlines profit structure and network operation will be influenced by internalization of external like emission charge. This additional cost caused by environmental requirement will affect to networks and profit structures of airlines according to the changes in demand.

The objective of this study is to evaluate the influence of carbon charges on airlines network behavior. The study conducts empirical research with a very specific case; that is to estimate the influence on flight network change for Incheon (ICN) – Frankfurt (FRA) route by application of carbon charge with EU-ETS concept, which has been requested by EU.

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Ⅱ. Research Method

2.1 Calculation of emission by aircraft

Research data used in this study are based on the 'Version 5 of ICAO Carbon Emissions Calculator' which issued on June 2012. It is a general methodology developed for estimating the amount of carbon emissions generated by a passenger in a flight, for use in carbon offsetting program of ICAO. It's designed to provide information on the methodological approach and details the assumptions of the generic factors employed by the ICAO Carbon Emissions calculator ICAO used this methodology to develop a Carbon Emission Calculator using a database constructed from several data sources. From the diagram below, it has been identified the following information used as input to the calculator:

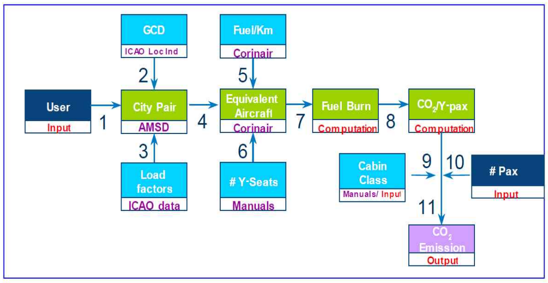

Figure 1 Recognition of emissions of ground and air transportation

CO_2 per Passenger = 3.157 * (total fuel * Passenger-to-Freight factor) / (number of Y-seats * Passenger load factor)

Where:

Total fuel = The weighted average of the fuel used by all flights departed from the origin airport in order to reach the destination airport. The weighting factor is the ratio of number of departures for each equivalent aircraft type, to the total number of departures.

Passenger-to-Freight factor = is the ratio calculated from ICAO statistical database based on the number of passengers and the tonnage of mail and freight, transported in a given route group.

Number of Y-seats = the total number of economy equivalent seats available on all flights serving the given city pair.

Passenger load factor = the ratio calculated from ICAO statistical database based on number of passengers transported and the number of seats available in a given route group.

3.157 = constant representing the number of tonnes of CO2 produced by burning a tonne of aviation fuel.

Source: ICAO Carbon Emissions Calculator (Version 5, June 2012).

There are many different Carbon Calculation system developed by the States and carriers to evaluate emissions caused by air transport. However, ICAO Carbon Emissions Calculator is the most general methodology which provided in an open source format facilitating individual air carriers that may wish to customize it with their own data. It includes a general description of the method adopted by ICAO in order to estimate the CO2 emissions, a demonstration of the data coverage and sensitivity and the steps needed to be taken by a carrier wishing to customize the calculator with its own data set.

2.2 Carbon charges' influence on airline costs and demand

Environmental costs are part of Direct Operation Cost and it can give direct influence on profitability of airlines. This additional cost caused by environmental requirement will affect to airline networks and profit structures of airlines. Eventually, this additional cost of airlines will be passed on to the passengers like fuel surcharge.

The calculations regarding the negative demand effect are based on price elasticity researched by Oum et al. (1992) as this study dealt with empirically estimated demand functions and fare elasticity measures for air travel. In general, when other influences on demand remain unchanged, a higher price for a product results in a lower quantity demanded. Demand of air passenger will be decreased due to increase of carbon price. In this paper, -0.82 of price elasticity in the mixed air passenger category from the research of Oum et al. (1992) will be used for empirical research.

III. Route selected for empirical study and fuel consumption

For empirical case study to conduct a research of airline network changes influenced by emission charges especially under the constraint of EU-ETS, subject air routes have been selected. In this study, the impact of environmental charges will be discussed when EU-ETS applied to aviation market. Between ICN airport and EU airports, the most frequent travel volume EU airport is Frankfurt Main International Airport (FRA). Thus, ICN to FRA route has been selected for empirical study.

The EU-ETS is the first and the largest emissions trading scheme in the world which launched in 2005 to response rapid climate change and also EU climate policy.

Total participated countries of EU-ETS as of 2014 are 31 countries which are all 28 EU member states plus Iceland, Norway, andLiechtenstein.

Depend on EU-ETS definition, all carriers arrive to EU airports and depart from EU airports will be applied regardless the nationality of the carrier. It is calculated based on the total amount of the emission produced on each flight. For the purpose of comparison on the cost and demand assessment, three different flight routes and airlines has been selected in the Table 1.

Table 1 Selected flight routes and airlines for cost and demand assessment

Flight routes			Airlines	Aircraft Type
Origin	Stopover	Destin.		
ICN		FRA	LH	A340
ICN	ZRH	FRA	KE / LH	B777 / A320
ICN	DXB	FRA	EK	A380 / B777

For the empirical analysis, individual routes are selected based on two criteria: the typical flight patterns through, to and from Europe and the extant variance in ETS-effects on different routings between origin and destination pairs. The direct flight between Incheon (ICN) and Frankfurt (FRA) is fully included in the EU-ETS, whereas with the two-segment flight via Zurich (ZRH) only the ZRH-FRA sector is subject to the ETS as ZRH is ETS-evasion airport even it’s located in Europe because Switzerland is non-EU country. As a same concept, with the two-segment flight via Dubai (DXB), only the DXB-FRA sector is subject to the ETS. In this context, it has been identified that ZRH and DXB are potentially attractive ETS-evasion stopover opportunity airports. The DXB transit airport located in Middle-East is especially interesting for airlines flying from/to the ICN, South Korea as it has price competitiveness.

On each flight routes, typical airlines and aircraft type has been selected for realistic appraisal and practical research. There are two typical direct service carriers from ICN to FRA routes which are Lufthansa (LH), German carrier and Korean Air (KE), National Flag carrier. For the direct service route, LH has been used for comparison. There is a direct flight service from ICN to ZRH by KE, however passenger have to use other foreign carrier service for the onward ZRH/FRA sector as no onward connection service is provided by KE. In this case, ticket price is higher than single carrier services to the final destination.

At the same time, airport charges and other environmental costs such as noise charge, environment tax, etc. will be imposed for the additional landing in ZRH airport. It may countervail ETS-evasion stopover benefit.

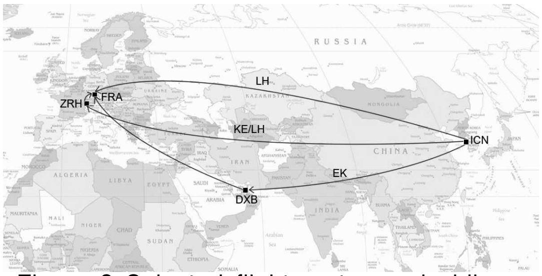

Figure 2 Selected flight routes and airlines for cost and demand assessment

In case of Emirates (EK) transiting in DXB, it has onward sector connection service out of DXB Hub. At the same time, airport user charges are relatively lower and no other environmental charges imposed to the carriers for the present. The Dubai Hub of EK is quite far away to deviates significant traffic via its Hub due to EU-ETS, especially from the Far-East airports. However, its network operations are extreme model of Hub-and-Spoke, so their multitude of other advantages that are competitively more significant than this ET-ETS related cost advantage. EU-ETS cost of ZRH airport transit might be lower than Middle-East airport transit schedules, but total cost of stopover in ZRH has not much of competitiveness as we have to consider other environmental costs of ZRH airport such as noise charge and also landing charge is higher than airports in middle-east.

Table 2 Distance and average fuel consumption data

Flight routes			Distance (km)			Average fuel consumption (kg of fuel)		
Origin	Stopover	Destin.	1st leg	2nd leg	Total	1st leg	2nd leg	Total
ICN		FRA			8,534			89,084
ICN	ZRH	FRA	8,732	285	9,017	61,517	1,855	63,372
ICN	DXB	FRA	6,721	4,836	11,557	3,319	39,321	92,640

The distance and average fuel consumption data based on ICAO Carbon Emissions Calculator are indicated in the Table 2. It has been applied to one-way economy class passenger basis for each sector.

Ⅳ. Estimation of carbon prices

It is not easy to forecast precise level of the carbon price for short-term, mid-term and long-term as it will be influenced by the various factors include economic growth, people’s real income, relevant regulations, decision of policy-makers, and so on. There are many different opinions and arguments regarding the way of forecasting future carbon price. Generally, it is difficult to provide accurate information on the average price of carbon offset credits at any moment in time as prices can and do fluctuate. According to expert estimations, the current market price can be assumed to range between €10/tonnes and €30/tonnes of CO2. The average EU Allowance (EUA) price on the third EU-ETS trading period which is from January 2013 until December 2020 will be €22/tonnes of CO2 according to Thomson Reuters Point Carbon. EU-ETS prices are expected to increase more rapidly towards the end of the third EU-ETS trading period and estimated prices are expected to reach €28/tonnes in 2020.

According to the UK’s Committee on Climate Change, it is suggested that a price of £30 per tonne of carbon dioxide equivalent in 2020 and it will be rise to £70 per tonne in 2030. In light of recent research results, the price of carbon should rise steadily even the rate of increase are all differ. General forecast is that it should increase at a constant rate close to the real rate of interest which will be 3% to 5% per year.

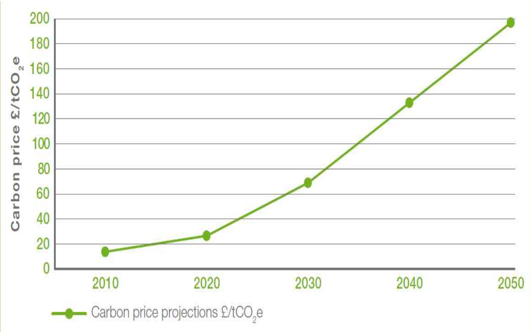

Figure 3 Carbon price projections (£/tCO2e)

Source: DECC (2010), EC (2010), CCC calculations

Some other reports and researches also support these forecast which is the increasing trend of carbon charges for long-term. In spite of various efforts in the aviation sector to reduce and neutralize carbon emission such as improve engine and airframe technologies, high energy-density fuel options, aircraft operational options, policy and regulation options, etc., but it's difficult to catch up the speed and amount of carbon emission increase. Global civil aviation will grow worldwide steadily and the negative impact of aviation on the global climate change also will be increased. We all have to work together to reduce and find out a reasonable solution. At the same time, civil aviation has to find the best airline network model to cope with this change.

Ⅴ. Emission charge's influence on airfare and demand

To access the CO2 emissions per flight, the fuel consumption has to be combined with the specific CO2 emission factor. The distance and average fuel consumption data based on ICAO Carbon Emissions Calculator of flight routes options are provided in Table 3.

Carbon dioxide emission is produced in direct proportion to the combustion of kerosene as the dominant jet fuel: Per kg of kerosene on combustion in the aircraft engine, 3.15kg of CO2 is emitted.

Table 3 Result of CO2 emission and the impact assessment of the EU-ETS

Flight routes			Average CO2 emitted per passenger (kg of CO2)			Additional cost per passenger (€22 / tons of CO2)		
Origin	Stopover	Destin.	1st leg	2nd leg	Total	1st leg	2nd leg	Total
ICN		FRA			562.98			12.39
ICN	ZRH	FRA	566.13	53.05	53.05	0	1.17	1.17
ICN	DXB	FRA	452.84	333.54	333.54	0	7.34	7.34

To access the additional costs of each flight associated with the EU-ETS, the estimated quantity of CO2 emissions per flight is multiplied with the expected market price for CO2 emission allowances.

To understand actual impact of EU-ETS charge on the existing flight routes, actual sample has been selected and compared in the Table 4.

Table 4 Air ticket fare and CO2 emission per passenger depend on flight routes

Flight routes	Airlines	Net air ticket fare (KRW)	Taxes (KRW)	Ticket fare (KRW)	CO_2 emitted per pax
P2P ICN/FRA	LH	2,090,000	656,900	2,746,900	1,125.96
ICN/ZRH/FRA	KE/KH	2,210,000	701,000	2,911,000	106.10
ICN/DXB/FRA	EK	1,735,000	550,900	2,285,900	667.08

Unit of air ticket fare: KRW (Korean Won) / Round Trip
CO_2 emitted per passenger: kg of CO_2

It is difficult to compare air ticket fare of different flight routes and carriers because there are various kinds of discounted tickets include promotion fares are exist in the market. For fair comparison, 1 year valid round trip ticket fare plus taxes has been used for comparison and to cope with average CO2 emission of ICAO Carbon Emission Calculator.

According to the UK's Committee on Climate Change, it is suggested that a price of £30 per tonne of carbon dioxide equivalent in 2020 and it will be rise to £70 per tonne in 2030, £135 per tonne in 2040 and £70 per tonne in 2050.

Table 5 Additional ticket fare per passenger depend on flight routes

	Flight routes	Airlines	2020 30£/tCO^2 (KRW)	2030 70£/tCO^2 (KRW)	2040 135£/tCO^2 (KRW)	2050 195£/tCO^2 (KRW)
P2P	ICN/FRA	LH	58,160.00	135,706.67	261,720	378,040
H&S	ICN/ZRH/ FRA	KE/KH	5,480.46	12,787.73	24,662.06	35,622.97
	ICN/DXB/ FRA	EK	34,457.15	80,400.02	155,057.18	223,971.48

Exchange rate: 1£ = KRW 1,721.79

Based on this forecast, ticket fare will be increased due to EU-ETS carbon price increase when we assume that other conditions are remains the same.

Table 6 Air ticket fare reflected EU-ETS charges depend on flight routes

	Flight routes	Airlines	2020 30£/tCO^2 (KRW)	2030 70£/tCO^2 (KRW)	2040 135£/tCO^2 (KRW)	2050 195£/tCO^2 (KRW)
P2P	ICN/FRA	LH	2,805,060	2,882,606.67	3,008,620	3,124,940
H&S	ICN/ZRH/ FRA	KE/KH	2,916,480.46	2,923,787.73	2,935,662.06	2,946,622.97
	ICN/DXB/ FRA	EK	2,320,357.15	2,366,300.02	2,440,957.18	2,509,871.48

Exchange rate: 1£ = KRW 1,721.79

Air ticket fare reflected EU-ETS charges depend on different flight routes such as direct flight, transit via ZRH and transit via DXB has been calculated in the Table 6.

Table 7 Increase rate of ticket fare forecast

	Flight routes	Airlines	2020 30£/tCO^2 (KRW)	2030 70£/tCO^2 (KRW)	2040 135£/tCO^2 (KRW)	2050 195£/tCO^2 (KRW)
P2P	ICN/FRA	LH	2.12%	4.94%	9.53%	13.76%
H&S	ICN/ZRH/FRA	KE/KH	0.19%	0.44%	0.85 %	1.22%
	ICN/DXB/FRA	EK	1.51%	3.52 %	6.78%	9.80%

According to the forecast of carbon price by the UK's Committee on Climate Change, it will rise steadily at a constant rate close to the real rate of interest. Based on this, it is assumed that ticket fare reflected EU-ETS charge will be also increased.

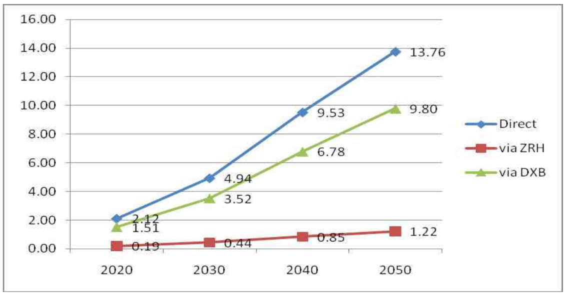

Figure 4 Increase rate of ticket fare forecast

And EU-ETS will be charged to the carriers flying from or to EU airports, increase rate of direct flight from ICN to FRA will be much higher than other flight routes which are via DXB and via ZRH as these airports are EU-ETS evasion airports.

Table 8 Demand decrease forecast due to increase of carbon price (2020~2050)

	Flight routes	Airlines	2020 30£/tCO^2 (KRW)	2030 70£/tCO^2 (KRW)	2040 135£/tCO^2 (KRW)	2050 195£/tCO^2 (KRW)
P2P	ICN/FRA	LH	-1.74	-4.05	-7.81	-11.29
H&S	ICN/ZRH/ FRA	KE/KH	-0.15	-0.36	-0.69	-1.00
	ICN/DXB/ FRA	EK	-1.24	-2.88	-5.56	-8.03

Price elasticity: -0.82 (Oum et al.)

On the other hand, demand of air passenger will be decreased due to increase of carbon price. In this paper, -0.82 of price elasticity in the mixed air passenger category from the research of Oum et al. (1992) has been used

for empirical research. It is defined that price elasticity which used in this study is the maximum value.

As indicated in the Figure 5, air passenger demand of direct flight will be decreased a lot more than other transit flight routes. Based on this result, it is assumed that EU-ETS evasion airports outside of EU countries will be used as transit airports, if EU-ETS is commercialized as planned. And also EU base carriers will be negatively influenced in the competitive air travel market.

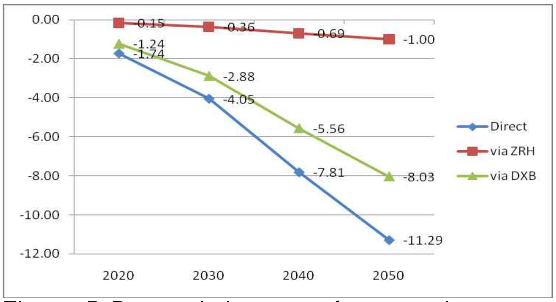

Figure 5 Demand decrease forecast due to increase of carbon price (2020~2050)

Ⅵ. Airlines network behavior influenced by emission charges

The result of this study illustrates the differences between the cost increases for direct and stopover flights via ZRH and DXB respectively due to aviation inclusion into the EU-ETS.

Lufthansa's direct flight routing leads to additional cost of €13.45 per trip per passenger whereas Korean Air and Emirates are partially affected as they have stopover airports out of EU territory. Korean Air's flight from ICN via ZRH and connection to Lufthansa flight to FRA results in additional cost of €1.14 per trip per passenger only. The effects of rerouting via non-European Hub to avoid ETS costs are visible: the routing via ZRH saves €12.31 in cost per trip per passenger. However, if we consider actual situation, other external costs should be take into accounted. Emirates flight from ICN via DXB to FRA results in additional cost of €7.59 per trip per passenger as EU-ETS charges will be applied to DXB/FRA sector only.

The negative demand effects influenced by internalization of external costs will be of a significantly larger importance for the European Hub carriers: whereas cost increases due to emission trading will affect non-EU carriers only on selected routes, EU carriers will see almost their whole network as eligible for ETS-evoked costs. Therefore, EU-Hub carriers will lose their passengers due to increases in air-fares over their whole network, compared to non-EU-Hub carriers that will lose this traffic only on their routes to and from the European Union airports.

The most energetic and fast growing typical competitors for European and Asian carriers are Middle-East based airlines such as Emirates, Qatar Airways and Etihad Airways.

They have been interpreted as a major benefactor of the EU-ETS introduction in the aviation market. Actually, the Dubai Hub of EK is too far away to deviate significant traffic via DXB due to EU-ETS binding, they enjoys a multitude of other advantages

that are competitively more significant than this EU-ETS related cost advantage. Actual impact to aviation market is not significant at the meantime as the price of carbon offset credits is not highly enough to reallocate network operations of major carriers at this stage. However, it is expected that the price of carbon offset credits will gradually increase.

So, it will be important to estimate and prepare the network operation strategies of each carrier. Current dominant airline network, Hub-and-spoke model will be affected by the increase of environmental charges include carbon charges more than Point-to-point network model as flying distance is relatively longer and also more frequent landings and take-offs will lead the increase of total operation costs of the airline.

In the long term, it will possible to give influence to airlines' route network due to carbon charge increase as direct operating cost will be increased.

Ⅶ. Conclusion

New implementation of EU-ETS charges will be affected to Korean aviation market especially to Europe destinations flights. Since EU-ETS charges will be based on flying distance from departing airport to EU airports, direct operating cost of long-haul route airlines to EU airports will be affected more than medium-haul or short-haul route airlines. Between Far-East Asia and EU routes, transiting via Middle-East is more favorable than direct operation since CO2 emission charge is calculated on the basis of flying distance and fuel burned. So, it implies a cost disadvantage for long-haul route direct operating flights. However, EU-ETS charge is still acceptable level for air passenger and the ticket price impact of EU-ETS charge addition is not severely affected to the passenger behavior of airline choice at this present. And also environment issue is not importantly considered in the Korean aviation market yet. However, environmental issue will last and also various environmental costs will be imposed and amount also gradually increased.

There is certain limitation of this research because this study has been made based on the assumption of EU-ETS application in the aviation. As discussed in the 38th ICAO general assembly in 2013, global ETS will be developed and MBM

scheme will be applied to the international aviation, in future. When global ETS applied to the aviation, transit thru the nearest airports of EU flight route will be no longer beneficial than direct flights to EU airports. And hereafter research regarding this issue will be required as environmental bindings on the global aviation will last.

EU-ETS is limited to EU region airports and there are some evasion air routes are available. However, there's no exception in the scenario of Global ETS.

According to the consent of the 38th ICAO general assembly in 2013, Global ETS will be developed and applied in the global aviation after 2018 at the earliest even there are many expected and unexpected barriers. Thus, it is important to tackle the problem and have to find a feasible network solution of the carriers.

후기

본 연구는 International Forum on Shipping, Ports and Airports에서 발표한 내용을 수정 보완한 논문입니다.

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