論文

# Influence of $CO_2$ constraints to airlines by EU-ETS on passenger behavior

Baek Jae Kim* Kwang Eui Yoo*, Youn Chul Choi**

# EU-ETS로 인한 항공사의 탄소비용증가가 항공여객에게 미치는 영향

김백재*, 유광의*, 최연철**

## ABSTRACT

유럽연합(EU)은 2012년부터 항공산업에 대해 탄소배출권 거래제도를 적용할 예정이다. 따라서 유럽공항에서 출발 및 도착하는 모든 국제선과 국내선 항공편에 대해 탄소세가 부과될 것이며 이는 한국도 예외는 아니다. 또한 유럽을 운항하는 경우 장거리에 해당되어 중단거리를 운항하는 항공기들에 비해 총 탄소배출량이 더 많으므로 비용부담이 커질 것으로 예상된다. 본 연구는 EU-ETS로 인한 탄소세가 항공요금에 반영된다면 항공여객들이 어느 정도 민감하게 반응할 것이며 이러한 점들이 궁극적으로 한국의 항공시장에 어떤 영향을 미칠 것인지를 파악해 보는데 목적이 있다. 이를 위해 인천국제공항에서 프랑크푸르트 국제공항 노선을 이용하는 승객을 대상으로 직항노선과 중동지역 경유노선을 비교하여 EU-ETS 가격이 반영된 항공요금에 대한 반응을 Revealed Preference (RP)와 Stated Preference (SP) 설문자료와 Logit Model을 사용하여 분석하였다. 본 연구결과는 한국의 항공산업은 물론 2012년부터 부과될 EU-ETS에 대한 항공사들의 전략개발에 도움이 될 것이다.

**Key Words** : Environment(환경), Emission Trading Scheme(배출권거래제), RP(Revealed Preference), SP(Stated Preference), Logit Model(로짓모델), CO2 Emission Charge(탄소세)

## I. Introduction

Air Travel contributes to climate change like other transportation methods and causes environmental and economic damage by its $CO_2$ emission. The contribution of the aviation sector to $CO_2$ emissions is only about 3% for the mean time, where as 19% are caused by road transportation. However, the real impact of air travel $CO_2$ emissions may be twice as high or even higher compared with $CO_2$ emissions on the ground. Because aircraft emissions are unusual in that a significant proportion is emitted at a high altitude. These emissions give rise to important environmental concerns regarding their global impact and effect on air quality at the ground level.

Aviation demand grew rapidly in the past decades and it is expected that this growth will be continued(Boeing, 2007; de Haan, 2008; Horton, 2006). At the same time, fuel consumption and $CO_2$ emission of aviation sector grew about 2~4% in the past decades and it is expected to grow further(Schlageretal., 2007) also. The demand for air transportation has increased steadily over the years. Passenger numbers have grown by 45% over

2011년 8월 12일 접수 ~ 2011년 9월 19일 심사완료
* 한국항공대학교
** 한서대학교 항공학부
연락저자, E-mail : pilot@hanseo.ac.kr
충남 태안 남면 신온리 산 105 한서대학교

the last decades and have more than doubled since the mid-1980s. Further, freight traffic has increased even more rapidly: by over 80% on a tone- kilometer performed basis over the last decade and almost three-fold since mid -1980s. (VETS Report, ICAO, 2007) Expected technological innovations cannot prevent an increase in $CO_2$ emissions from aviation sector due to the high increase in demand(deHaan, 2007). The Inter governmental Panel on Climatic Change (IPCC) completed a report on the effects of aviation on the global climate and is a much cited reference in this field(Penneretal.,1999).

The European Council and the European Parliament agreed in July 2008 to include international aviation into the existing European Union Emissions Trading Scheme (EU-ETS) for the limitation of $CO_2$ emissions. The Directive came into force in February 2009(Council of the European Union, 2009). Aircraft operators will be obliged to surrender allowances for all commercial flights landing at and departing from any airport in the EU from 2012 onwards. With this legislative process, the EU-ETS will not only include airlines based in the EU, but in fact all carriers operating at airports in the EU. Therefore, flights from South Korea to EU will be also affected. This paper analyses how the EU Directive for the inclusion of international aviation into the EU-ETS will affect the international air transportation sector especially to Korean Aviation Market.

The EU Directive, as it came into force in February 2009(Council of the European Union, 2009) contains the following provisions for the inclusion of aviation into the existing emissions trading scheme:

- The emission trading scheme will cover all flights departing from or arriving at EU airports from 2012 onwards.
- Aircraft operators will be the responsible entities for holding and surrendering allowances for $CO_2$ emissions.
- Regulations for emission monitoring and reporting will take effect in 2010 while an emission cap for all aircraft operators will be introduced in 2012.
- The EU Directive for the period 2013~2020 (Council of the European Union, 2008), as it was agreed in December 2008, aims at improving and extending the greenhouse gas emission allowance trading system of the Community.

The cost effects for passengers will depend to a large extent on the ability of airlines to pass through cost increases to the demand side. Similar to the imposition of fuel surcharges in recent years due to high oil prices, it can be expected that airlines will be able to pass through a large extent of the cost increase. If airlines will be able to pass through only the acquisition costs of allowances to be purchased in addition to the free allocation, we expect an average cost increase per ticket. The cost increase for long-haul flights can be substantial, if the complete trip is subject to the EU-ETS and acquisition as well as opportunity costs will be passed on to the passenger. Direct operating cost of long-haul route airlines to EU airports will be affected more than medium-haul and short-haul route airlines. Between Far-East Asia and EU routes, transiting via Middle-East is more favorable than direct operation since $CO_2$ emission charge is calculated on the basis of flying distance from departing airport to EU airports. So, it implies a cost disadvantage for long-haul route direct operating flights.

The objectives of this paper are as follows: After an overview of the influence of $CO_2$ constraints to aviation industry and EU Directive as it contains provisions for the inclusion of aviation in the existing emissions trading scheme, we'll assess which major factors influencing air flight choice in the market were found through the RP(Revealed Preference) data analysis. And these factors will be adopted as attributes for the SP(Stated Preference) experiment, as they have reality as identified through observed behavior. Charging for aviation emissions or terrestrial greenhouse gas emissions requires a price to be put on the value of one tonne of carbon dioxide. The exact charge for $CO_2$ emissions levied by an offsetting company is also a subject matter. We have used basic measures of the cost of carbon dioxide emissions based on IPCC guideline(김민정, 안미진, 2008).

Table 1. IPCC Guideline(Aviation Emission)

| | Emission Index (kg/TJ) | | |
|---|---|---|---|
| FUEL | $CO_2$ | $CH_4$ | $N_2O$ |
| Aviation Gasoline | 70,000 | 0.5 | 2 |
| JET A-1 | 71,500 | | |

EU-ETS assign an economic value to emissions of carbon dioxide. Under such market based schemes, the price is variable and is strongly influenced by supply and demand. At the time of survey EU-ETS is currently trading at EUR 10 per tonne of carbon dioxide. So, we have worked on the assumption that KRW100,000(approximately USD90) of EU-ETS charge will be added to the ticket price of direct flight from ICN to FRA and KRW50,000 (approximately USD45) will be added to the ticket price of transit via Middle-East flight based on the current carbon calculating system. The calculation for the volume of $CO_2$ produced on the flight is based on actual operating performance rather than an industry average. It takes account of the fuel consumed, the relative efficiency of the aircraft and the number of passengers carried. As an imperical research, A330 and B777 airraft type has been used to calculate expected EU-ETS charge per passenger under the 80% of average load factor. It has ensured that it's operating procedures, as far as possible to minimize environmental impact. And then, we will gather information thru the survey from the passengers what is their preferable choice. It will be focused on the passenger's reaction and choice of the respective airfares reflecting EU-ETS $CO_2$ emission charge to find out the influence to the South Korean aviation market.

To calibrate a disaggregate transport choice model, the data about observed choice, called revealed preference (RP) data, have been generally used up to the mid-1980s. However, RP data have some practical limitations: (a) they frequently show insufficient variation for some variables of interest to calibrate an accurate statistical model, (b) it is often difficult to estimate model parameters reflecting the proper trade-off ratios because of strong correlations between explanatory variables of interest, and (c) very large surveys may have to be carried out to obtain sufficient observations to calibrate statistically accurate models. Stated preference (SP) techniques that use respondents' statements about preferences in a set of transport options can overcome the shortcomings of the RP method because researchers have control over composition of hypothetical alternatives. The drawback of SP techniques is that the data obtained represent individuals' statements of what they would do given hypothetical choices. However, people may not do what they say. This disadvantage can be somewhat overcome by presenting respondents with as realistic a set of situations as possible. This work used SP and RP data, gathered by the surveys, to complement the shortcomings of each method.

## 2. Survey and Data Preparation

The questionnaire for the survey was composed of three parts. The first part was for the flight information, for example Nationality of Airlines, Flight Time, Intermediate-stop Airport, Purpose of Travel, Reasons to choose this flight, and so on. The second part was for personal socioeconomic information. The third part was the main information of analysis including questions related to flight choice procedure and the opinion about the chosen flight.

The survey to gather RP data was conducted at the passenger terminal of Incheon Internati onal Airport in South Korea, in May 2011. The questionnaires were distributed to the passengers going to the FRA airport from ICN airport. The survey distributed a total of 120 questionnaires and 119 questionnaires were collected. A total of 11 questionnaires were eliminated from the analysis because of a lack of consistency.

A total of 108 collected questionnaires were fully utilized as a sample. The useful data for this research were selected according to following principles. (1) The observations from which the round trip ticket price between Incheon International Airport (ICN) and Frankfurt Main Airport (FRA) could be identified were included in the useful data set. Almost all package travelers and one-way travelers were excluded. A few business travelers whose journeys were paid for by their companies or organizations were also excluded by this principle. (2) Travelers who were going to stay more than 24hours at intermediate-stop cities were excluded because their ticket price might include the extra charge for the stopover. (3) The observations that missed the information about the flight number were excluded. With a missing flight number, it is impossible to validate flight time to destination and airline. (4) Only passengers using scheduled flights were included.

The most serious concern about this data selection is that business travelers who their company or organization purchased the tickets were excluded from the sample set. This could have caused bias in sampling and the representativeness of the sample could have been damaged(YOO. K. E., and Norman Ashford, 1995).

## 3. Analysis of Data

Since Nationality of airlines, Journey time and Air Fare were identified as major variables; the Logit model was calibrated against those variables to test the hypothesis that travelers prefer National carriers, short journey time and low air fare and identified the degree of importance of those variables for flight choice in the market.

Based on this hypothesis, we have included expected EU-ETS charges to direct flight and transit flight via Middle-East to identify the changes of passengers' choice behavior whether it's affected.

Table 2. Cost to offset $CO_2$ Emission (Direct versus Transit Flights)

| Carrier | Flight No | Origin | Transit | DSTN | A/C Type | Flying Time | Price (KRW) | CO2 (Ton) | Offset cost (USD) | Distance (Mile) |
|---|---|---|---|---|---|---|---|---|---|---|
| Asiana Airlines | OZ541 | ICN | | FRA | B747 | 11:30 | 1,816,800 | 2.45 | 18.37 | 10,617 |
| Korean Air | KE905 | ICN | | FRA | B777 | 11:45 | 1,809,600 | 2.45 | 18.37 | 10,617 |
| Lufthansa | LH713 | ICN | | FRA | A340 | 11:40 | 1,460,300 | 2.45 | 18.37 | 10,617 |
| Qatar Airways | QR883 | ICN | DOH | | A330 | 10:15 | | | | |
| | QR025 | | DOH | FRA | A330 | 6:35 | 1,437,000 | 1.26 | 9.48 | 5,696 |
| Emirates | EK323 | ICN | DXB | | A380 | 9:30 | | | | |
| | EK045 | | DXB | FRA | B777 | 6:50 | 1,480,600 | 1.34 | 10.01 | 6,015 |

Logit models were calibrated with the economy class observations only, excluding the observations of first class and business class travelers. The input value for the Logit calibration was defined and decided for the chosen alternative as well as rejected alternatives.

The utility function of the model could be written as:

$$U=\beta_0+a_1 Nation+a_2 JT+a_3 Fare+a_4 EU\text{-}ETS$$

Where Nation = Nationality of Airlines (0: Korean, 1: Foreign)

JT = Air Journey Time (Min)

Fare = Air Fare (KRW)

EU-ETS = EU-ETS charge (KRW)

$a_1$, $a_2$, $a_3$, $a_4$ = coefficients to be estimated.

The sign of all parameters of each calibrated model is 'Right', This means that travelers preferred National carriers, short journey time and low air fare. It confirms that the traveler choice behavior accorded with the hypothesis of the study.

### SP Design, Survey and Model Calibration

All the factors influencing air passengers' flight choice should be included in the attribute set to understand travelers' behavior. However, it must be pointed out that few respondents are consistently adept at evaluating many attributes at a time. Therefore, it is a major concern at their initial stage of SP design to select a few important attributes and set their level considering reality and simplicity of the hypothetical alternatives. The major factors influencing air flight choice in the market were found through the RP data analysis as described which are follows; Nationality of airlines, Air journey time and Air fare. These three (3) factors can be adopted as good attributes for the SP experiment, as they have reality as identified through observed behavior.

### Response Measurement Scale

Three kinds of measurement scales have been used for SP experiments: ranking across options, rating each option, and choices among options. The discrete choice approach is realistic and easier for interviewees because individuals in real environments do not rank or rate travel alternatives; they choose one of them. Moreover, the survey environment of this research was compatible with choice experiments because the survey was conducted in the check-in counter and boarding gate area of Incheon International Airport, and the respondents did not have enough time to consider rating or ranking the alternatives. Therefore, it was decided to conduct the choice exercise as an SP experiment.

### SP Questionnaire Composition

The questionnaire was composed of two parts. The first part was for segmentation of the samples for the customization of the attribute levels. The second part was for the main SP experiments, which were composed of a pairwise choice game of hypothetical alternatives. There were 12 choice pairs constructed from 6 alternatives. Among the 12 pairs, 6 pairs were composed of one dominated alternative and one dominant alternative in every aspect of the attribute level, and other 6 pairs were composed of competitive alternatives, since it is difficult for one respondent to answer many choice pairs in a short time.

### Binary Logistic Regression Result

Table 3. Case Processing Summary

| Un-weighted Cases [a] | N | % |
|---|---|---|
| Included in Analysis | 648 | 100 |
| Unselected | 0 | 0 |
| Total | 648 | 100 |

a. If weight is in effect, see classification table for the total number of cases

Table 4. Omnibus Tests Model Coefficients[a,b]

| Omnibus Tests | | -2 Log Likelihood | Constant |
|---|---|---|---|
| Step | 1 | 890.742 | -0.216 |
| | 2 | 890.742 | -0.217 |

a. -2 Log Likelihood: 890.742

b. Estimation terminated at iteration number 2 because parameter estimates changed by less than .001.

We can see from the table above that we are modeling 648 cases here. Some cases are deleted from the analysis where information is missing. The SPSS default for this is listwise.

Only cases where all dependent and explanatory variables are complete are included in the analysis.

Table 5. Classification Table[a]

| Observed | | | Predicted | | |
|---|---|---|---|---|---|
| | | | Airlines[b] | | % Correct |
| | | | 0 | 1 | |
| Step 0 | Airlines | 0 | 359 | 0 | 100 |
| | | 1 | 289 | 0 | 100 |
| Overall % | | | | | 55.4 |

a. The cut value is .500

b. National Carriers (0), Foreign Carriers (1)

Table 6. Variables in the Equation

| | | B | S.E. | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|---|
| Step 0 | Constant | -0.217 | 0.079 | 7.532 | 1 | 0.006 | 0.805 |

Table 7. Variable not in the Equation

| | | | Score | df | Sig. |
|---|---|---|---|---|---|
| Step 0 | Variables | Airlines | 351.61 | 1 | .000 |
| | | Journey Time | 164.096 | | .000 |
| | | Air Fare | 392.333 | | .000 |
| Overall Statistics | | | 437.562 | 3 | .000 |

We have added one new variable to the model, which has reduced the -2 log likelihood by 890.742 with 1 degree of freedom. The -2 log likelihood is a measure of how well the model explains variations in the outcome of interest.

Table 8. Classification Table[a]

| Observed | | | Predicted | | |
|---|---|---|---|---|---|
| | | | Airlines[b] | | % Correct |
| | | | 0 | 1 | |
| Step 1 | Airlines | 0 | 332 | 27 | 92.5 |
| | | 1 | 44 | 245 | 84.8 |
| Overall Percentage | | | | | 89 |

a. The cut value is .500

b. National Carriers (0), Foreign Carriers (1)

The -2 log likelihood (sometimes called, deviance) has a chi squared distribution. It is important to optimize likelihood in the logistic regression analysis. As 2LL value is 890.742 in this model, it is statistically significant.

Table 9. Variable in the Equation

| | | B | S.E. | Wald | df | Sig. | Exp(B) | 95.0% C.I. for EXP(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower | Upper |
| Step 1[a] | Nation | -21.797 | 2602.874 | 0 | 1 | 0.993 | 0 | 0 | . |
| | JT | -3.435 | 0.732 | 22 | 1 | 0 | 0.032 | 0.008 | 0.135 |
| | Fare | 1.736 | 0.299 | 33.789 | 1 | 0 | 5.672 | 3.159 | 10.183 |
| | Constant | 20.636 | 2602.874 | 0 | 1 | 0.994 | 9.17E+08 | | |

a. Variable(s) entered on step 1: Nationality of Airlines, Air Journey Time and Air Fare

A regression utility function could be written as:

U= 20.636 - 21.797 Nation - 3.435 JT+1.736(Fare+ EU-ETS)

Where Nation = Nationality of Airlines (0: Korean, 1: Foreign)

JT = Air Journey Time (Min)

Fare = Air Fare (KRW)

EU-ETS = EU-ETS charge (KRW)

According to the survey result, we have come up with utility function about this research. As we have negative numbers about the nationality of airlines and air journey time, these factors will be affected to the passengers' behavior when other conditions are the same. So, this hypothesis has been verified through experiments. It is valid that Wald figures of JT and FARE in the table of variables in the equation, thus odd rate of JT is 0.32 (32%) and odd rate of FARE is 5.67 (567%) respectively.

However, we have concluded that air fares reflecting EU-ETS $CO_2$ emission charge is not severely affected to the passenger behavior of airline choice in South Korean aviation market. It is analyzed that EU-ETS charge amount which we use d in this paper is not expensive enough to affect to passenger behavior and also environment issue is not importantly considered in the South Korean aviation market yet.

## 4. Conclusion

SP and RP methods have their drawbacks. The most efficient way might be to use both methods in a way to complement each other with comparative analysis. It is usual that there

are some discrepancies between models calibrated from different data even though the subject market and considered variables are the same. This study also indicated some discrepancies between RP and SP models. However, proper interpretation of discrepancies would be helpful in understanding the choice behavior in the market. The values estimated from the RP model may be useful for demand forecasting or some other realistic purposes, and values estimated from the SP model may be useful for system planning purpose. In addition, the discrepancies between those two kinds of models can also be a useful index for transport planners because RP models represent the real situation and SP models represent the intentions of consumers. Although the RP and SP models are not well reconciled, the discrepancies are well explained and the results could be useful for Air Transportation planners in the market.

Because this is the first study concerning choice behavior under the situation of EU-ETS charge inclusion to the air fare in the Korean air transportation market, it will provide a base for further research and also for aviation market. In addition, it shows that research using RP and SP data gathered through the similar survey environment can complement the drawbacks of each method, and the application of SP techniques to the air transport choice problem was usefully validated.

New implementation of EU-ETS charges from 2012 will be affected to Korean aviation market especially to Europe destinations. EU-ETS charges will be based on flying distance from departing airport to EU airports, so direct operating cost of long-haul route airlines to EU airports will be affected more than medium-haul and short-haul route airlines and it will be considered depend on the amount of actual EU-ETS charges.

According to the survey result, we have come up with utility function about this research. As we have negative numbers about the nationality of airlines and air journey time, these factors will be affected to the passengers' behavior when other conditions are the same. However, we have concluded that air fares reflecting EU-ETS $CO_2$ emission charge is not severely affected to the passenger behavior of airline choice in South Korean aviation market.

Further research is recommended after actual EU-ETS charge is levied to the carriers operating at airports in the EU.

## REFERENCES

[1] Boon, B., Davidson, M., Faber, van Velzen, A., Allocation of allowances for aviation in the EU ETS: The impact on the profitability of the aviation sector under high levels of auctioning. Final report. 2007

[2] Choi, Y. C., Emissions Trading Scheme of Aviation Market and its Impact, Korean Society for Aeronautical Science and Flight Operation, Seminar, 2008

[3] EUROCONTROL, User Manual for the Base of Aircraft Data (BADA) – Revision 3.6, ECC Note No. 10/04. 2004

[4] Faber, J., van de Vreede, G., Lee, D. S., The Impacts of the Use of Different Benchmarking, Methodologies on the Initial Allocation of Emission Trading Scheme Permits to Airlines. 2007

[5] ICAO, Report on Voluntary Emissions Trading for Aviation (VETS) Report, 2007
[6] IPCC, The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment, Report of the Intergovernmental Panel on Climate Change, Cambridge, UK and New York, NY, 2008
[7] Kim, B. J., Yoo, K. E., and Choi, Y. C., A Study on Impact of Voluntary CO2 Offsets Program on the Korea Aviation Industry, Journal of the Aviation Management Society of Korea, 2009
[8] Kim, M. C. and Ahn, M. J., Estimated Volume and Scheme of Greenhouse Gas Emission for Air Transportation, The Korea Transport Institute, 2007
[9] Kim. Y. G., and Haites, E. F., Greenhouse Gas Emission Trading Schemes: Recent development and policy recommendations for Korea, environment Institute, 2005
[10] Kroes, E., and R. Sheldon. Stated Preference Methods, An Introduction. Journal of Transport Economics and Policy, Vol. 22, No. 1, 1988
[11] Pearmain, D., J. Swanson, E. Kroes, and M. Bradley. Stated Preference Techniques: A Guide to Practice, 2nd ed. Steer Davies Greeve and Hague Consulting Group, London, Engl and, 1991
[12] Yoo, K. E., and Norman Ashford, Carrier Choices of Air Passengers in Pacific Rim: Using Comparative Analysis and Complementary Interpretation of Revealed Preference and Stated Preference Data, Transportation Research Record 1562, 1995
[13] 이 재우, EU-ETS 탄소배출권 가격 결정요인 분석: 단기 및 중기적 요인을 중심으로, 수은 해외경제, 2008
[14] 김민정, 안미진, 항공교통 부문 온실가스 배출규모추정 및 관리방안, 한국교통연구원, 2008
[15] 김백재, 유광의, 최연철, 한국 항공산업의 자발적 $CO_2$ 감축프로그램의 영향에 관한 연구, 한국항공경영학회지, 제7권 제4호, 2009