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Willingness to pay price for tolls and on-board units for short-distance freeway users who normally avoid toll boots

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ABSTRACT

This study explored the willingness to pay price for tolls and on-board units (OBUs) for short-distance freeway users who did not pass through toll stations and further explored the willingness to pay price for different user groups. Those users would be legally obliged to bear the brunt of freeway costs instead of avoiding the payment of any out-of-pocket costs. As expected, the implementation of ETC has not been successful because of the travel patterns of freeway users. The spike model was adopted in this study to minimise estimation errors caused by users who were unwilling to pay. The estimation results revealed that compared with other user groups, short-distance freeway users who did not pass through toll stations were less willing to pay for an OBU. In addition, the willingness to pay price for tolls increased with travel distance. In addition, this study demonstrated that short-distance freeway users who did not pass through toll stations evinced low levels of willingness to pay due to various factors, such as "low freeway usage rate", "trips that occurred during off-peak hours", and "short travel time".

1. Introduction

The first freeway in Taiwan, Sun Yat-sen Freeway, was constructed to develop the Taiwanese economy and bridge the gap between the urban and rural areas of Taiwan. The construction of the Sun Yat-sen Freeway commenced in 1971, and this freeway was first opened to traffic in 1978. In accordance with the "user pays" principle, road users who directly benefit from a freeway should share the costs of freeway construction and maintenance; therefore, to collect freeway usage fees, manual toll stations were installed on the national freeway, with an average interval of approximately 37.3 km between each pair of stations. The popularity of private passenger cars in recent years has resulted in increased freeway usage. Based on national transportation policies, an electronic toll collection (ETC) system was introduced to enhance the efficiency of passing through toll stations and to reduce carbon emissions. The Far Eastern Electronic Toll Collection Company (FETC) was responsible for ETC under the build-operate-transfer (BOT) model of civil operations. The ETC system began operating in full on February 10, 2006. Initially, both manual toll collection and electronic toll lanes were used, but it is expected that by 2013, the freeway tolls will be completely converted from manual payments per trip to ETC.

To utilise the ETC system built by the FETC, drivers must purchase and install an on-board unit (OBU) in their vehicles. However, because of cost considerations, OBUs cannot be provided free of charge. The Taiwanese public is dissatisfied with the OBU's asking price of NT$680[1]; this dissatisfaction has been reflected in the usage rate of the ETC system (the 2011 ETC system usage rate was 41.65%), which remains far below the target ETC usage rates proposed by the Ministry of Transportation and Communications (Table 1), resulting in long delays in the promoted policies.

Jou et al. (2011a, 2012, 2013) studied issues related to the complete implementation of ETC on Taiwanese freeways and used the structural equation modelling (SEM) framework to explore the impact of various dimensions on the willingness to use an ETC system. Among those investigations, Jou et al. have used econometric models to estimate the prices that drivers are willing to pay (WTP) for an OBU and the tolls of an ETC system (Jou et al., 2012, 2013).

The above studies have demonstrated that approximately 2.5–2.6 million trips are made daily on Taiwanese freeways. More than 60% of these trips did not pass through toll stations, indicating that most freeway users travelled a distance of less than 50 km and avoided passing through toll stations (henceforth, users who travel less than 50 km will be referred to as short-distance freeway users). To achieve a fair "pay as you go" system of payments for freeways, the implementation of ETC system is required. It is, therefore, important to investigate the related behaviour regarding ETC system of this specific group since they would consider themselves as losers. Their rights of short-distance freeways users

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[1] $1.00=NT$30.00

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Table 1
Target ETC usage rates.
Source: Tender documents for the national freeway electronic toll collection system.

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	By the end of contract
Usage rate (%)	15	30	45	60	65	70	75	80	85	90

to use freeways, used to avoid passing through toll stations, would be legally obliged to bear the brunt of freeway costs instead of avoiding the payment of any out-of-pocket costs. As expected, the implementation of ETC would be rebounded by this type of freeway users.

Based on the above-mentioned reasons, this study studied short-distance freeway users who did not pass through toll stations.[2] The objective of this study was to continue the work of Jou et al. (2012, 2013) by exploring the OBU and toll prices that these freeway users were WTP after the implementation of an ETC system. Jou et al. (2012, 2013) investigated a topic that was similar to the subject of this study; however, these prior studies did not explore issues that were related to short-distance freeway users.

Previous studies in other countries have used statistical analysis, descriptive statistics, and individual choice models to explore the topics that relate to different aspects of ETC systems, including not only the hardware requirements, new technologies, and legal basis of ETC schemes (Lee et al., 2008) but also privacy exposure concerns and ETC promotional strategies (Riley, 2008). Olszewski and Xie (2005) adopted an individual choice model to investigate the impact of different pricing rates during off-peak times in the contexts of city centres and freeways; furthermore, these researchers discussed the impact of vehicle models, freeway conditions, individual departure times, and travel routes on fees. Certain studies modified the SEM approach to create new models (such as the theory of planned behaviour and the technology acceptance model) for exploring the low usage rate of ETC equipment and ETC services (Chen et al., 2007).

Because a certain proportion of freeway users do not wish to pay to use the freeway or to purchase an OBU, attempts to estimate the willingness to pay prices of freeway users with logit or probit models are prone to estimation errors (Hanemann, 1984; Salvador, 2001). Given this issue, many studies have used spike[3] models to avoid errors caused by respondents who answered "0" as their willingness to pay price (Kristroöm, 1997; Saz-Salazar and Garcia-Menendez, 2001; Yoo and Kwak, 2002; Yoo et al., 2006; Bengochea-Morancho et al., 2005; Hu, 2006; Jou et al., 2011b, 2012, 2013).

In summary, this study will also utilise a spike model to estimate the toll and OBU prices that short-distance freeway users are WTP. Since the main purpose of the study is to explore issues that are related to short-distance freeway users, the spike model is not our focus. Besides, the method has been adopted in studies by Jou et al. (2012, 2013); interested readers may refer to these studies. The remaining sections of this paper are organised as follows. Section 2 describes the questionnaire design and data analysis of this investigation, Section 3 presents the results of the estimation model and policy suggestions, and Section 4 provides conclusions and suggestions for future studies.

[2] The users travel along a parallel road to avoid the toll stations. In our study, only users who avoided toll stations and engaged in trips that were less than 50 km in length are the subjects of the subsequent analyses.

[3] Tobit model was not employed because it cannot capture the effects of zero response while the spike model has this advantage, especially when the samples contain a significant portion of zeros.

2. The model

Kristroöm (1997) proposed the use of a spike model to resolve the issues that arise when the reported price users are WTP is zero or negative, which has been proven to be superior to other traditional models, such as logit and probit models. It is better for a number of reasons. Firstly, also the major advantage, it can recognise the respondent's response equals to zero. In this study, many respondents (above 10%) are not willing to pay any money to use freeways. Secondly, the results in traditional models always under-estimate compared to the results of the spike model, as the former one does not account for zero willingness to pay.

The spike model assumes that the individual's utility function can be written as follows:

$$U(Y,X,Q)=V(Y,X,Q)+\varepsilon \tag{1}$$

where Y is income, X is a vector of socioeconomic characteristics, Q is a vector of the asset value and ε is a random disturbance term with zero expected value. When users are WTP for a distance-based toll (or OBU), it means that they prefer the new state (V_1) over the current state (V_0) (meanwhile their asset value will alter from the current asset (Q_0) to the new asset (Q_1). Thus, the individual's utility can be rewritten as follows:

$$V_1(Y-A_1,X,Q_1)+\varepsilon_1 \geq V_0(Y,X,Q_0)+\varepsilon_0 \tag{2}$$

when the user is WTP for a distance-based toll(or OBU), their income will be reduced by A_1, though they still prefer the new utility V_1. We assume an income equal to Y in the initial stage, V_0 ($Y_0=Y$), and ε_0 and ε_1 are random terms with an independent and identical (iid) Gumbel distribution. Thus, the probability function that a given user pays the amount A_1 in the new state can be derived as follows:

$$\begin{aligned} &V(Y-A_1,X,Q_1)-V(Y,X,Q_0)\geq \varepsilon_0-\varepsilon_1\\ &\Pr(\text{Yes})=\Pr(\Delta V(*)\geq \varepsilon)=F_\varepsilon(\Delta V(*)) \end{aligned} \tag{3}$$

where $\Delta V(\cdot)$ indicates the difference between the utilities of the new state and the current state. Moreover, if the bid A_1 offered in the questionnaire is smaller than the willingness to pay value (willingness to pay $\geq A_1$), it means that the traveller will pay that amount A_1 to use the freeway. The probability of individual paying the amount A_1 in the new state can be derived as follows:

$$\begin{aligned} \Pr(\text{Yes})&=\Pr(\text{willingness to pay}\geq A_1)\\ &=1-G(A_1)\\ &=F_\varepsilon(\Delta V(*)) \end{aligned} \tag{4}$$

where $G(A_1)$ is the cumulative distribution function (c.d.f.) of the respondent who is not willing to pay the amount A_1. The domain of the cumulative distribution function can then be expressed as follows:

$$G(A_1)=\begin{cases} 0, & A_1<0\\ P, & A_1=0\\ F(A_1), & A_1>0 \end{cases} \tag{5}$$

we can further derive the expected willingness to pay as follows:

$$\begin{aligned} E(\text{willingness to pay})&=\int_0^{\infty}(1-G(A_1))\,dA-\int_0^{-\infty}(G(A_1))\,dA\\ &=\int_0^{\infty}(F_\varepsilon(\Delta V(*)))\,dA-\int_0^{-\infty}(1-F_\varepsilon(\Delta V(*)))\,dA \end{aligned} \tag{6}$$

where p belongs to (0,1) and $F(A_1)$ is a continuous and increasing function such that $F(A1=0)=p$ and $\lim_{A_1\to\infty} F(A_1)=1$. The maximum likelihood function for the sample is then given as follows:

$$\begin{aligned} L=&\sum_i^N M_iW_i\ln(1-G(A_1))+\sum_i^N M_i(1-W_i)\ln(G(A_1)-G(0))\\ &+\sum_i^N(1-M_i)\ln(G(0)) \end{aligned} \tag{7}$$