WILLINGNESS-TO-PAY FOR EXPRESSWAYS

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ABSTRACT

This study is about the willingness-to-pay (WTP) for an expressway service. For eliciting WTP, we have used a part of large scale congestion pricing survey and asked seven hypothetical questions to respondents who were users of the Hanshin Expressways networks. The questions asked respondents to choose between a toll road and surface streets with different travel times, travel time variability. A certain constraint about the arrival time at the destination was imposed. We used prospect theoretic concepts of reference time point as the zero asset position in place of the coupling time; and with respect to the reference point a late arrival is indexed as a loss, an early arrival is indexed as a gain. Using reported WTP, we have conducted different regression models in order to evaluate different hypotheses. To do so, we have divided the regression analyses into two groups with the first group comprised of the general regression analyses used for open-ended valuations, i.e., multiple regression and log-linear regression analysis. The second group of regression analyses, i.e., the stochastic frontier and Tobit regressions, bears the hypotheses that the reported WTP is a bit lower than the real WTP and for the expressway there is a upper limit capacity value which is similar to willingness-to-accept (WTA).

The first hypothesis is derived by a consideration that respondents might have a concealment value, which is the difference between real WTP and the reported WTP. We believe that it is generally lower then the real WTP and locate this hypothesis by using the stochastic frontier regression model. The results of the stochastic regression analysis support the existence of concealment value. As future research, we conclude that complex and flexible models to locate different concealments in different settings and an explicit frontier are needed. In this regard, explicit frontier might be the responds given to the alternative that bears the most loss or pure loss.

The second hypothesis is derived from the economic literature on equivalent and compensating variations, which refer to different valuations in welfare gain and welfare loss settings. The capacity value that might be similar to the WTA in the context of the welfare gain is assumed to be the upper limit for the Tobit regressions. In this regard, two capacity values have been employed; they are the values of 75th percentile and 90th percentile of the responds to the pure loss question presented to the respondents. As a result of the regression analyses, it is found that the best model is the Tobit model using the 90th percentile of the WTP values of the pure loss question.

Generally in the regression analyses, it has been found that the risky alternatives are ranked by WTP values proportional to their risk levels; in other words, a high risk level displays high WTP. Commuters who use the expressway everyday value the use of it higher than commuters who use the expressway two or three times a week. Females generally value the highway higher than the males.

Apart from the regression analyses, in the early sections preliminary analyses based on paired t-tests suggest that the gains decrease significantly at a distant position from the reference time point (coupling time) than a near location. Although similar inference cannot be found in the loss region, we have found that the loss is significantly higher than the gain for a similar interval in both of the gain region. The findings are supportive of the prospect theory in the context of route choices based on travel time variation and coupling time.

1. INTRODUCTION

Changes in consumer surplus has been approached in two different ways (Hicks 1943, 1956): one is the compensating variation (CV), which is the amount of income that an individual is ready to pay to keep his utility as it was before a change; the other is the equivalent variation (EV), which is the money individual is ready to accept to accept a low level utility. For welfare gains, CV and EV are known to be willingness-to-pay-WTP (to attain the gain) and willingness-to-accept-WTA (to accept the non-occurrence of the gain) respectively; but for a welfare loss, CV and EV refers to WTA-(to compensate the loss) and WTP (to prevent the loss). It has been shown that these WTP and WTA are different (Hammack and Brown. 1974). Substitution effect (Hanemann, 1991; Shrongen et al. 1994), income effect (Willig, R. D. 1976), loss and gain disparity (Brookshire and Coursey 1987; Kahneman and Tversky,. 1979), endowment effect (Thaler, 1980), property rights (Coase, 1960), and transaction costs (Brown and Gregory 1999) have been found to account for the WTA/WTP disparity. Generally, measuring either CV or EV in the form of WTP and WTA can be based on revealed preferences, stated preferences or offers made to customers (Sattler, 2002). Among these, stated preference (SP) studies are based on behavioral intentions and responses to hypothetical choice settings. Conjoint Analysis (CA) and Contingent Valuation Method (CVM) are two special cases of SP methods (Ben-Akiva et. al. 1994). The main difference between CA and CVM is that CA asks for a ranking, ratings or choices of multiple products based on product profiles; while in CVM, WTP is directly asked (open-ended) or inferred from responses to referendum yes-no questions (close-ended) for a bid or a sequence of bids (McFadden, 1994; Kalish and Nelson 1991).

In this study, we try to estimate willingness-to-pay for expressway service by using a stated preference survey with hypothetical settings. Thus it might be helpful to shortly introduce general WTP studies for transportation services. The WTP studies in transportation are generally fed by value of travel time savings from pursuing a better mode or a better route. Thus these studies generally reflect CV in welfare gain, i.e., WTP. This approach is true when, for a commuter, an expressway or an automobile generally mean a reliable and fast (as well as possibly safe and comfortable) trip; thus welfare gains by superior alternatives are used to materialize as Value of Travel Time (VOTT) and/or Value of Reliability (VOR) that generally reflect WTP. WTP is needed for the operator, who might use it to achieve different purposes: maximization of profits or social welfare or etc. For the operator, tolling an expressway can be regarded as a value pricing policy[1], because in normal circumstances, driver saves time by avoiding congestion assumed to exist on surface streets. Besides, WTP studies are also used for justifying infrastructure investments in transportation; for example, in the UK, Mackie et al. (2001) notes that travel time savings accrue to 80% of the monetized benefits. Among others, we can mention Calfee and Winston (1998), Small et al. (1999), Lam and Small (2001), Brownstone et al. (2003) as recent studies on VOTT as proxy for WTP for reduced travel time. If we trace the studies back to the early 1960s, most of the VOTT studies have originated from discrete choices on travel mode or route. However, Calfee and Winston (1998) have noted that VOTT derived from a mode choice model, that captures the disutility differences among different modes is contextually different and may be misleading. Most of the studies concentrate on the superior characteristics along with generally accepted personal characteristics, age, sex, occupation etc. Time pressures are generally captured by time of day phenomenon and travel time variability as differences because of the nature of the discrete choice. In none of the WTP studies on time pressure such as coupling time vis-à-vis present time (e.g., a commuter departure) has been used explicitly. In this study, the experiments are conducted by using different coupling time, travel time variability on surface streets.

This study is a continuation of a series of studies on commuters' departure time choice deploying prospect theoretic concepts (Jou and Kitamura, 2002; Senbil and Kitamura, 2004; Fujii and Kitamura, 2004). The approach that we have pursued in the previous studies features temporal reference points for a typical

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[1] Value pricing is defined as a policy that offers a better service at a higher price. See ITE Task Force (1998)

commuter: earliest and latest acceptable arrival times at the work location. A risk aversive commuter would select a departure time which would assure an arrival in the acceptable (gain) region which spans the two reference points; a risk seeker is assumed to behave reversely, and have a positive probability of falling in the unacceptable (loss) regions, i.e., before the earliest or after the latest arrival time. In the previous studies, we have estimated the value function based on commuter satisfaction at the end of each commute. Another important element of prospect theory, the weight function, is computed by superimposing the range of possible commute trip arrival times on the gain region defined by the two reference time points. Generally, in our studies it has been shown that departure time choice is consistent with prospect theory. As a continuation by using similar concepts, in this study we show that stated WTP for an expressway trip vis-à-vis a surface street trip structurally changes when coupling time as reference is changed. We conclude that, ceteris paribus, demand for expressway trips is dependent on temporal reference points defined by the coupling time and travel time variation on surface streets.

In the sections that follow, we explain changes in consumer surplus and how they are viewed in certain conditions in section two. The section three explains the experiments (seven in total) along with preliminary analyses. The forth section introduces the econometric model for WTP and the results of the estimations based on the models devised. The last section concludes the study with the findings and implications for further research.

2. CHANGES IN CONSUMER SURPLUS

Consumer surplus is the measure of the difference between the monetary amount that can be paid for certain amount of a good or service and the monetary amount actually paid for the amount consumed. Researchers are interested mostly in the change of the consumer surplus induced by new policies or investments, because measurement of this change makes it possible to elicit measures of WTP or WTA. In neoclassical economics[2], analysis of consumer surplus change has been refined by Hicks (1943) and Hicks (1956), which have proposed two generic measures, i.e., CV and EV, CV is the change in income necessary to restore the consumer to his original indifference curve (Varian, 2003) before a change. Thus, it measures the amount of money required to maintain satisfaction, or economic welfare, at the level before the change. EV is the amount of money that leaves a person as well off as before, after a change. In other words, it is the amount of money that would be taken away from the consumer before the price change to leave his as well off as he would be after the price change (Varian, 2003). In general, for welfare gains we know that CV equals to WTP and EV equals to WTA; for welfare losses, CV equals to WTA and EV equals to WTA. Besides, for price changes EV and CV measure are quite close to each other, and the difference is proportional to the income elasticity of demand for the good (see Willig, 1976). Following is the derivation of the CV and EV from both Marshallian and Hicksian Demand functions.

The simplest version decision making is one of utility maximization subjected to an exogenous budget constraint. The indirect utility function is the solution of that problem:

$$\nu(\mathbf{p}, y) = \max \upsilon(\mathbf{x}) \quad \text{s.t. } \mathbf{p}' \cdot \mathbf{x} = y$$

where $\upsilon(\mathbf{x})$ is the quasi-concave utility function, $\mathbf{x}$ is the vector of the consumption levels of goods, $\mathbf{p}$ is the corresponding price vector, and y is income, which is being treated as exogenous. The maximization problem yields the Marshallian demand functions:

$$\mathbf{x} = m(\mathbf{p}, y)$$

[2] By this we mean, individual has preferences over all nonnegative bundles of consumption goods with properties of transitivity, continuity, increasingness, and convexity (see Varian, 2003).

This demand function characterizes the behavior that can be typically observable and relevant for measuring the utility that is unobservable. In a simple setting, using the indirect utility function, CV of a change in the price from an initial value, $\mathbf{p_0}$, to a final value, $\mathbf{p_1}$ can be defined as, CV is given by:

$$v\left(\mathbf{p^0}, y^0\right) = v\left(\mathbf{p^1}, y^0 + CV\right)$$

Note that CV is in money terms as the change in income necessary to restore the utility level before the change in the price vector. CV is indeed a measure of compensation. In some studies (e.g., Willig 1976, and Hausman) CV has been defined more concretely as the compensation (positive or negative) that must be paid to return the consumer to his initial utility level. Therefore, if the price change makes the consumer better off, the compensation necessary to return him to his initial utility level must be negative, i.e., WTP, but if it makes him worse off then the compensation has to make him as before, i.e., WTA (see Figure 1).

The other measure proposed by Hicks (1943, 1956) is the EV measure, which is given by:

$$v\left(\mathbf{p^0}, y^0 + EV\right) = v\left(\mathbf{p^1}, y^0\right)$$

EV measure takes as the baseline the new level of utility that would be possible when the price change put into effect. EV is the adjustment of income necessary to achieve this new level of utility but without the price change. Thus EV is a compensation measure with a different benchmark. The benchmark is the utility level achieved after the change. The welfare measure is the change in income necessary to attain that utility level under the initial price circumstances. EV is equivalent to WTA for utility increases and WTP for utility decreases (Figure 1).

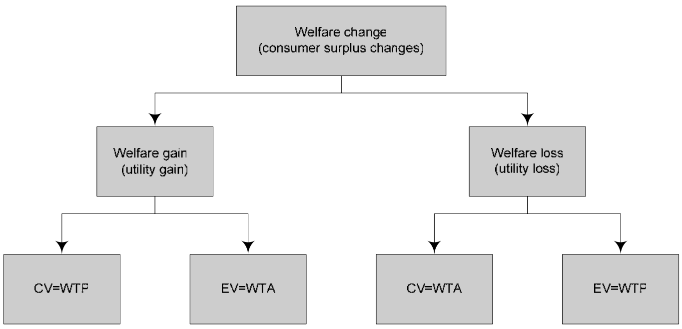

Fig. 1. Relations between CV, EV, WTP and WTA.

To illustrate the above argument (for the welfare gain case), we refer to Figure 2. Suppose that we have two goods, one is the composite commodity Y (measured in quantity), on the vertical axis, and the other is the consumption good X, which is a normal good and further suppose that there are two endowment points A (x_1,y) and B (x_2,y) for welfare changes. It can be seen that a move from A to B is a welfare gain and the reverse is a welfare loss. In this seting, if individual ceases a consumption of composite commodity Y in favor of X is measured as WTP (a downward move on Y axis), but if individual accepts an amount of Y in order to cease consumption of X is measured as WTA (an upward move on Y axis).

Then the four measures of consumer surplus change can be depicted as given in the four panels (a-d) of Figure 2. Increase in the consumption of X from x_1 to x_2 is compensated in a certain amount of Y that is viewed as WTP and the original welfare is restored (a), but the amount that is to be given in order to keep the individual at the welfare position attained by the Indifference curve II becomes WTA that measures equivalent Y that makes the individual better off (b). When we change our focus to welfare loss that is defined by the move from B to A, then WTP and WTA is mirrored in reverse order. To keep the individual in the original position B, which is at a better welfare state, individual is compensated by a certain amount of Y, which becomes WTA in this setting (c). Lastly, WTP in the welfare loss can be interpreted as the measure that the person ceases a certain amount of Y and becomes indifferent with the reduced consumption of X from x_2 to x_1 (d).

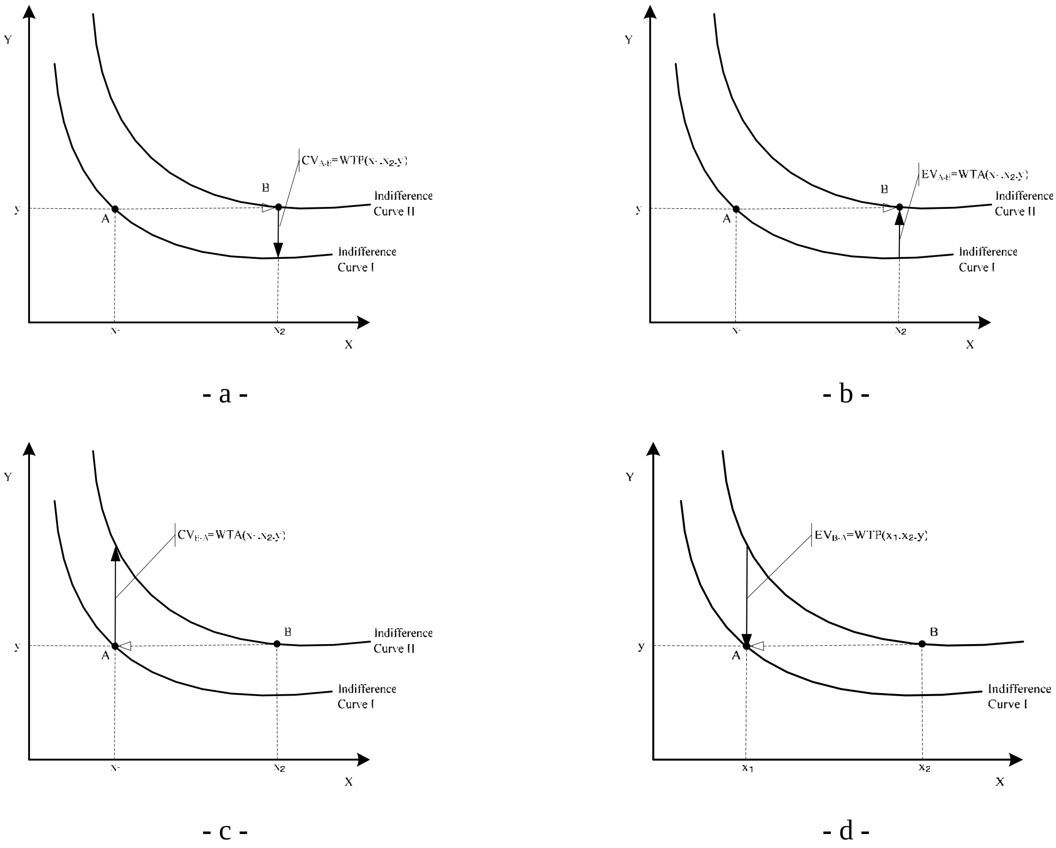

Fig. 2. CV, EV, WTP and WTA.

Having established certain links between theoretical derivations of CV and EV with WTP and WTA, we now turn to our focus to WTP and WTA. Initial theory of the WTP and WTA (through CV and EV) measures are thought to be equal (e.g., Henderson, 1941), but not so long after Hicks (1943) has noted that although they are equal in terms of utility, they are not equal in terms of money (p. 38) considering the marginal amount of spending on goods. Later, the difference has been noted by early empirical contingent valuation studies; for example, Hammack and Brown (1974) reports that respondents stated that they required great deal more compensation to give up a resource than they were willing to pay to obtain[3]. There is now a well-developed literature on the disparity between WTA and WTP. This disparity has persisted in various sorts of stated preference studies too. Generally, Substitution effect (Haneman, 1991; Shrongen et al. 1994), income effect (Willig, 1976), loss and gain disparity (Brookshire and Coursey, 1987; Kahneman and Tversky,. 1979), endowment effect (Thaler, 1980), property rights (Coase, 1960), and transaction costs (Brown and Gregory 1999) have been found to account for the WTA/WTP disparity. Interested readers are referred to general studies on this issue, e.g., Venkatackalam (2004). Following is short summary the findings on WTP/WTA disparity.

[3] Waterfowl hunters stated that they are willing-to-pay $247 (more) for hunting; but they are willing-to-accept $1044 to sell their rights.

As consumers are subject to income constraint, hence any spending has to be within the confines of the income; because of this reason, WTP reflects the constraint imposed by the budget implicitly. On the other hand, WTA does not have any constraint (Willig, 1976); of course, income elasticity has to be considered more carefully in this setting. In addition to income effect, Hanemann (1991) notes that substitution effect is also relevant in the WTP/WTA disparity, with greater disparity in commodities that do not have close substitutes. The study of Shrogren (1994) demonstrates that WTP and WTA values differ significantly between two groups of goods: the first one is a group of private goods (coffee mug and candy bar) and the second one is reduction of public health risk. The explanation that has come from the prospect theory is more straightforward as the theory states that individuals are more sensitive to losses than to gains (Kahneman and Tversky, 1979). Thaler (1980) has also added endowment effect on WTP/WTA disparity in addition to other the prospect theoretical explanations. Endowment effect on the disparity decreases if individual is endowed with a good amount of the goods in question.

Generally, WTP may be elicited from studies based on stated or revealed preference approaches[4]. The main objective of a willingness-to-pay study is to find out people's willingness and ability to pay for different service-levels by a demand driven approach in which the consumers are presented with a set of service levels which can reveal the actual willing-to-pay. Although estimates based on revealed preference has produced many insights; externalities, public goods and information asymmetries (McFadden, 1991) might interfere with the individual decision making, thus estimates based on stated preferences with hypothetical markets might perform better than the revealed preference approaches. Basically WTP studies are differentiated with respect to the survey methodology adopted; in general we differentiate three (Figure): i. Revealed preference, ii. Stated preference, iii. Offers to buy (Sattler, 2002).

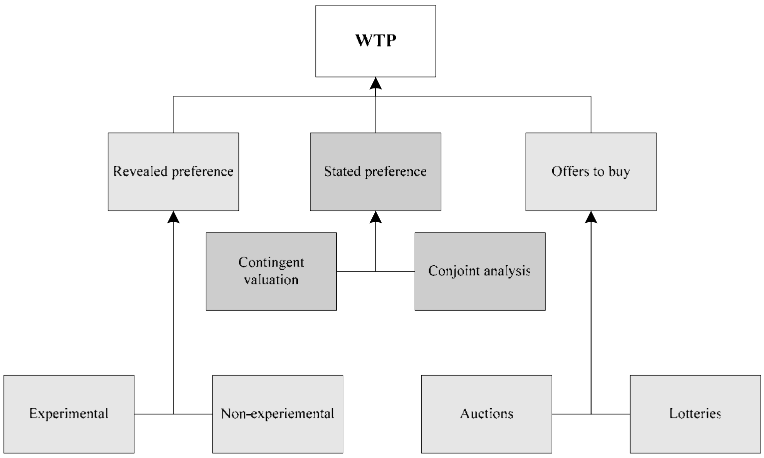

Fig. 3. Methodologies for eliciting WTP.

Revealed preference data might be obtained either from the real life transactions (Ben Akiva et al., 1994) or from laboratory simulation experiments. A particular difficulty in revealed preference is that either in the real life transactions or in the experiments, a transaction means that the WTP of a buyer is as high as the transaction cost, and WTP of those non-buyers stay below the transaction cost. Thus, stated preference data offers better elicitation of WTP over revealed preference. Two methods widely used in stated preference methodologies are Contingent Valuation method and Conjoint Analysis. Contingent valuation method (CVM) asks WTP either directly (open ended), or by referendum YES-NO strategy, tries to find

[4] Note that we have not encountered any study reporting WTA based on revealed preference approach, however there are many when the survey method switches to stated preference methodologies. From this point on we will generally refer to WTP because of the abundance of the studies on WTP, but the reader is advised to bear the applicability of most of the methods to WTA equally in mind.

the true interval where WTP falls. In this study, we have used an open-ended question format that will be made clear below. Conjoint analysis makes use of rankings, ratings or choices made upon different product profiles. The last methodology is offers to buy which is dominated by Vickrey type of auctions (Vickrey, 1961). In Vickrey type of auctions, a person's WTP is closely associated with the bidder bidded immediate below. Lotteries take on the legacy of the prospect theory: a person is first asked his WTP and then he is subjected to a lottery with a random draw of price, if this price is less than the reported WTP he has to buy (Sattler, 2002).

3. WTP FOR TRANSPORTATION SERVICES

WTP in transportation studies has generally been derived from value of travel travel time (VOTT) savings that can be attributed different causes such as to a mode, e.g., car vs. public transit, to a route e.g., freeway vs. [toll] expressway, to a destination e.g., city center vs. suburban, or even to a trip making pattern, e.g., mixed land use vs. monotony land use. Derivation of VOTT has been theoretically made possible by Becker (1965) which proposed that individual satisfaction comes from final commodities that use goods and services as well as time. researchers begun to use time as an element of the utility function with a fixed time budget, which have been used alongside monetary budget to obtain the indirect utility function. From those times, there has been accumulated a vast literature on VOTT, that will not reviewed here. Interested reader is referred to Small (1992) and Wardman (1998), the two general studies that provide comprehensive reviews on VOTT among others. A typical VOTT study involves a sampled individual evaluating the levels of service offered by an (existing) free route and a proposed tolled route. To the knowledge of the authors, most of the revealed preference or the stated preference VOTT studies derive relevant VOTT values from estimated disutility[5] functions; the method can be roughly expressed as follows (DeSerpa, 1971):

$$VOT = \frac{\partial \boldsymbol{\omega} / \partial t}{\partial \boldsymbol{\omega} / \partial c}$$

where **ω**, t and c stand for (estimated) disutility function, and its arguments in time and cost. This method implies an implicit trade off between cost and time. For example, studies Small (1992); Lam and Small (2001); Mackie et al. (2001), Brownstone et al. (2003) are examples of studies where this measure has been suggested. Calfee and Winston (1998) employs conjoint analysis and estimates VOTT directly by including the toll into the disutility function.

However, in discrete choice setting, the disutility functions, **ω** are expressed in differences (superiority, inferiority) over other alternatives in the choice set, and as the alternatives in the choice set are represented as a sum of observed and random error(s), parameters of the function are generally estimated by random utility maximization (see Ben Akiva and Lerman, 1985). Because of its nature, it is possible that this approach might bear bias slightly in the estimation of the real WTP (that cannot be corrected by using some statistical procedures) as the choice is assumed to be a relative phenomenon considering the differences in the disutility; this does not represent the (in)direct utility that a person can place on something, as expressed above. Besides, the VOTT computed from estimated disutility functions might be a mix of WTP and WTA (consider the case of captive riders). Although in all of the VOTT studies travel time is a pivotal element, other constraints such time pressures has not been represented. It might be the case that time pressures can play or change WTP in terms of coupling time, travel time variability[6]. Hence, WTP might not be a static phenomenon that can be applied in welfare studies or project evaluation

[5] Most of the time, travel is associated with negative utility; time is thought to be bygone and travel itself is thought to be discomfortable (noise, close contact with others) etc.

[6] Lam and Small (2003) includes this into Value of Reliability.

studies but rather a dynamic phenomenon that can change by coupling times. Coupling time is closely related to the time of day when the trip have been taken and the nature of the activities at the other end. In case of a commute, value attached to the travel time might be higher than the value of travel time to another activity with higher flexibility. Besides the use of coupling time in the WTP derivation might let us derive the measures to derive WTA which is not possible under the current methodology and use it as benchmark while driving WTP measures that are less than WTA in most of the cases. Using the prospect theoretical notions, a driver might be more sensitive to losses in time with respect to coupling than to the travel time variation, or else he might be more sensitive to arrivals around the coupling than to the arrivals far late or far early times. In order to locate the coupling time in WTP/WTA calculations, we have conducted experiments, which tries to simulate the real life conditions by presenting a coupling, travel time variations on two routes. The following is the detailed explanation of the experiments and their immediate results.

4. EXPERIMENTS

In this study, trips on surface streets, with which a commuter is endowed, are assumed to bear the risk of delay with respect to the reference time points (see Senbil and Kitamura, 2001 for reference time points); thus, a commuter would change the route from surface streets to expressways to secure a punctual (and riskless) arrival, but with the payment of a toll. In this respect, the commuter is asked to express an open-ended WTP which is assumed to be a composite monetary value for the travel time differential between fastest and slowest traffic conditions on both of the expressways and surface streets and coupling time. As conceptualized in the previous studies and as noted above, there are two temporal reference points: the earliest acceptable arrival time (EAT) and the latest acceptable arrival time (LAT). For simplicity, we assume that the latest arrival time is defined by an externally established coupling constraint, e.g., work starting time. EAT is the time that can be achieved when the commuter adopts the earliest departure time that is permissible to him. We do not make any assumption further than on the classification of the arrival times as loss and gain with respect to the coupling time, which is assumed to the reference time point. After converting the crude problem into gains and losses we set the coupling time as the zero asset position as devised by the prospect theory (Kahneman and Tvesrky, 1979).

We make use of a survey study, whose respondents are commuters passing through a certain section of the Hanshin Expressways in Osaka, Japan (Figure 4). The section is called Route 13 (R13) and extends east from the central parts of Osaka. The survey study was carried out in conjunction with the congestion pricing field experiment conducted over a six-week period. It consists of two surveys: the first survey was conducted prior to the field experiment and collected data on commute experience, e.g., average commute trip duration, and fastest and slowest auto trip durations ever experienced. This survey also included questions that asked the amounts respondents were willing to pay when they faced certain hypothetical conditions (discussed below). The second survey comprised commute trip diaries, which solicited data on departure time, commute duration, use of R13, etc., on weekdays (excluding holidays) between January 26, 2004 and March 5, 2004. Thus, 29 days worth of data have been gathered from each commuter respondent. The respondents were divided into two groups based on their reports on weekly use of R13 in the first survey, and each group of commuters are subjected to three different toll schemes over four periods during the field experiment.

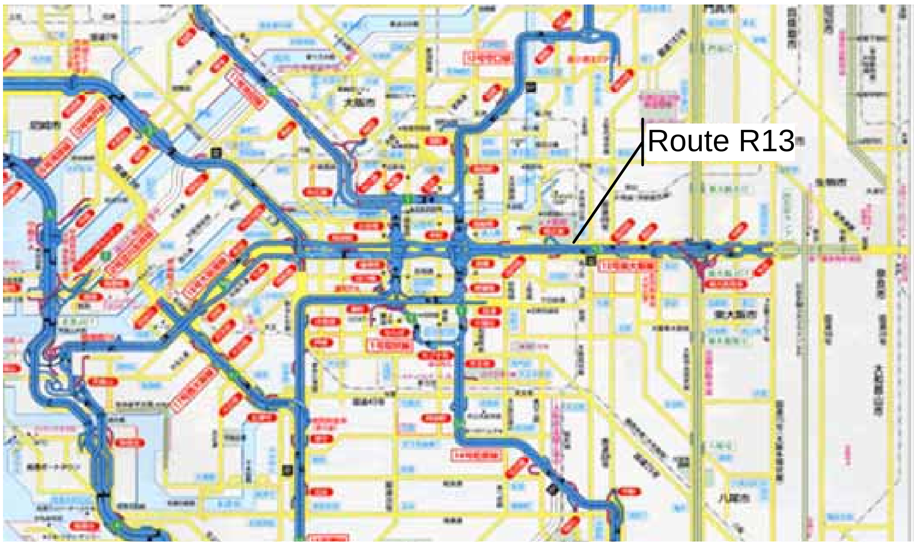

Fig. 4. The Hanshin east expressway network (deep colored lines represent the expressways)

In the study area, the Hanshin expressways are operated with two toll schedules. The first is flat rate tolls that are applied in three regions: Hanshin East (R13 is part of this region), Hanshin West, and Hanshin South, where passenger cars are charged ¥700, ¥500, and ¥500, respectively; the second schedule is applicable to trips over certain short segments of expressways and trips across regions[7]. There are toll reductions available in case of advance bulk purchase of toll coupons; coupons are available in quantities of 9, 24 or 100 at the prices of 8 (10% reduction), 20 (15% reduction) or 81 (18% reduction), respectively[8].

In the first survey, respondents reported WTP for expressway use under various combinations of constraints on arrival and uncertain travel times that might cause a loss because the travel time variation implied possible violation of the coupling constraint. In the WTP questions, an arrival constraint is presented to the respondent, combined with travel time characteristics associated with two options: use of surface streets that requires no monetary cost but involves a larger variation in travel time, bearing a larger risk of delay, and use of expressways that requires a toll but involves no delay. The reliable alternative, use of expressways, is presented to the respondent with a travel time variation of 10 minutes, i.e., the difference between the fastest and slowest possible travel times is 10 minutes. This is substantially less than travel time variations presented for surface streets, which are either 20 or 30 minutes. Seven WTP questions were asked to the respondents, each having a different coupling constraint and a different travel time variation on the surface street alternative (Table 1). The question is phrased in the questionnaire as follows:

> *Assuming that you are commuting or having a work related appointment at a place that are reachable by both surface streets or expressways; suppose that you want to be at your destination in X minutes; by taking expressways you will be at the destination in 35 to 45 minutes, and by taking surface streets you will be at the destination*

[7] Hanshin Expressway Tolls Map (in Japanese). www.hepc.go.jp/douro_ryoukin/index.html. Accessed August 14, 2004.

[8] Hanshin Expressway List of Tolls (in Japanese). www.hepc.go.jp/guide/guide-03d.html. Accessed August 14, 2004.

in FAST to SLOW minutes. If you were to take the expressways, how much toll would you pay?

In Table 1, questions are shaded in different colors according to the level of risk of late arrival. The length of the band of possible arrival times that fall before the coupling constraint, *X*, using surface streets is structured to be 15 (1), 10 (3), 5 (5) or 0 (7) minute when travel time varies by 20 minutes; and 25 (2), 15 (4) and 5 (6) minutes when travel time varies by 30 minutes.

TABLE 1 Experimental Design of WTP Questions for Expressway Tolls

Question	Coupling Time	Route	Trip Duration	
	X minutes after	(S: Surface Streets; E: Expressway)	*FAST* (minutes)	*SLOW* (minutes)
		E	**35**	**45**
1	*X* = 70	S	55	75
2	*X* = 75	S	50	80
3	*X* = 65	S	55	75
4	*X* = 65	S	50	80
5	*X* = 60	S	55	75
6	*X* = 55	S	50	80
7	*X* = 55	S	55	75

Assuming a prompt departure, the questions are mapped to a theoretical construct that we use throughout the study (Figure 4). The reference time point is computed as the time point that is found by adding the coupling time to the present time, and this time point has been given the absolute zero point for all couplings. The questions are plotted on the time scale by taking the differences of the coupling time with the slowest and fastest travel times. An early arrival is placed on the positive scale as it represents a gain, the reverse is done for an that is computed as a late arrival. Although, throughout the questions the expressway does not vary in terms of travel time variation, there is variation with respect to the location of expressway arrivals with respect to the reference time point. Thus a visual comparison of the questions asked to the respondents is made possible in Figure 4. With respect to the figure, Questions 1 and 2 present high probabilities of punctual arrival at the destination with respect to the late arrivals; Questions 5 and 6 represent the exactly reverse cases of Questions 1 and 2 respectively except for the expressway arrivals. Questions from 5 to 7 have low probabilities gain regions, and moreover most of the arrivals fall into the loss region. Questions 3 and 4 represent the cases when both of the gains and the losses are same in either gain or loss regions, they differ in travel time variation such that Question 4 is a five minutes enlarged version of Question 3 in either gain or loss regions. Also for both of the questions 3 and 4, the expressway stands at the same arrival points with respect to the reference time point. In all of the questions, expressway reveals latest arrival time either five or ten minutes before the earliest arrival times possible by the surface streets.

Question 7 deserves a special interest that a punctual arrival is not possible if commuter takes the surface streets. The WTP in this question might be viewed differently from the ones reported for other questions; in this regard, the monetary value reported might be WTA. Because in all of the questions, the commuters report values to avoid the losses in the face of gains; in other words, it might be the case they might arrive in the gain region, hence a higher utility is the endowment in this case and the value reported is WTP. In other words, in Question 7, as there are no gains, the commuters are endowed with an inferior indifference (see Figure 2 above), to restore an early arrival they have to move to the higher indifference curve and the value that they report should be EV or WTA.

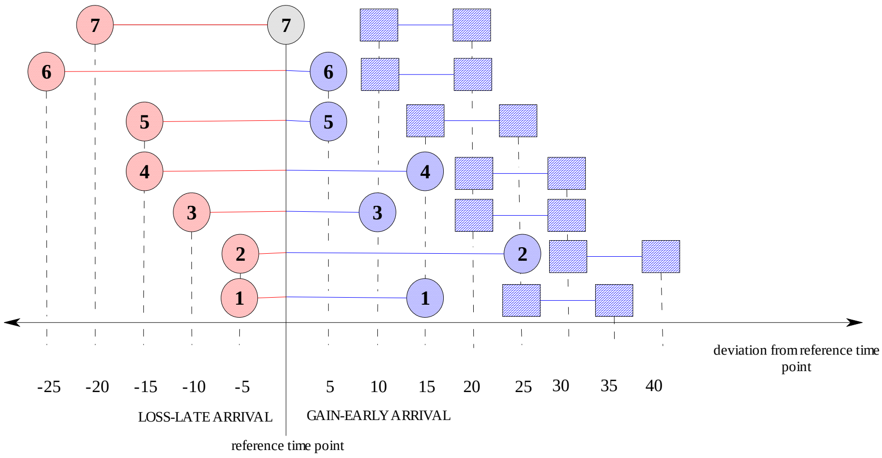

Fig. 5. Theoretical setting of the experimental questions (the lines between circles represent possible arrival time points surface streets offer, the lines between rectangles represent possible arrival times for expressways fixed to 10 minutes),

A total of 222 respondents out of 236 responded to the WTP questions. Mean WTPs for the respective questions show a certain degree of variability, but other summary statistics such as modes and medians show extreme regularity, saddling at ¥500 for all questions except medians of Question 6 and 7 for everyday users of R13 (Table 2). It might be the case that the reports bear some rounding errors to ￥500. When faced with low gain probability, respondents are risk aversive and increase their WTP. Interestingly, none of the mean values reaches the current toll of ¥700. WTP for expressways increases when risk of delay on surface streets increases. In other words, as the delay probability increases WTP increases on the average. Besides, it is worthy to note that, at equal levels of risk and same coupling time (i.e., Questions 3 and 4), reported WTPs increase by approximately ¥10 to ¥30 (a paired t-test yields that the difference is significant at a 2% level) with increasing travel time variations, i.e., 20 minutes in Question 3 and 30 minutes in Question 4. Thus, increase in travel time variation results in higher WTP, ceteris paribus. An impossible early arrival by surface streets (Question 7) causes the highest WTP for expressways by both types of users.

TABLE 2 Commuter Responses to Hypothetical WTP Questions (in Japanese Yens)

		Mean	Median	Mode	Std. Deviation	Minimum	Maximum
Expressway user 1: 2 or 3 times a week	Q1	559	500	500	311	100	2000
	Q2	544	500	500	293	100	2000
	Q3	537	500	500	268	100	2000
	Q4	567	500	500	309	100	2000
	Q5	581	500	500	319	100	2000
	Q6	598	500	500	306	100	2000
	Q7	611	500	500	347	100	2000
Expressway user 2: Almost everday	Q1	562	500	500	325	100	2000
	Q2	567	500	500	326	100	2000
	Q3	586	500	500	332	100	2000
	Q4	598	500	500	330	100	2000
	Q5	638	500	500	367	50	2000
	Q6	656	600	500	344	100	2000
	Q7	681	525	500	414	100	3000
All Users	Q1	561	500	500	318	100	2000
	Q2	557	500	500	311	100	2000
	Q3	564	500	500	306	100	2000
	Q4	584	500	500	320	100	2000
	Q5	613	500	500	347	50	2000
	Q6	630	500	500	328	100	2000
	Q7	650	500	500	387	100	3000

By closely inspecting Figure 5, one question can be observed as nested in another and one can notice these question pairs display different arrivals times in one side of the reference time point while having same arrival times on the other side. This allows us to inspect the changes in value (WTP or WTA) as a result of a surplus of arrival times only in one of the early or late regions. For the early region, the differences between question pairs 4-5 and 1-2 display different early arrivals while having late arrivals exactly same, i.e., questions 4 and 2 can result in arrivals 10 minutes earlier than their respective counterparts. For late region, question pairs 1-4 and 5-6 display different late arrivals while having the early arrivals exactly at the same time. In Figure 6, the differences in the gain region are labeled as G1 (4-5) and G2 (1-2); the differences in the loss region are labeled as L1 (5-6) and L2 (1-4). By comparing the differences in reported WTP that are captured by G1, G2 and L1 and L2, we can gain some idea about the value functions.

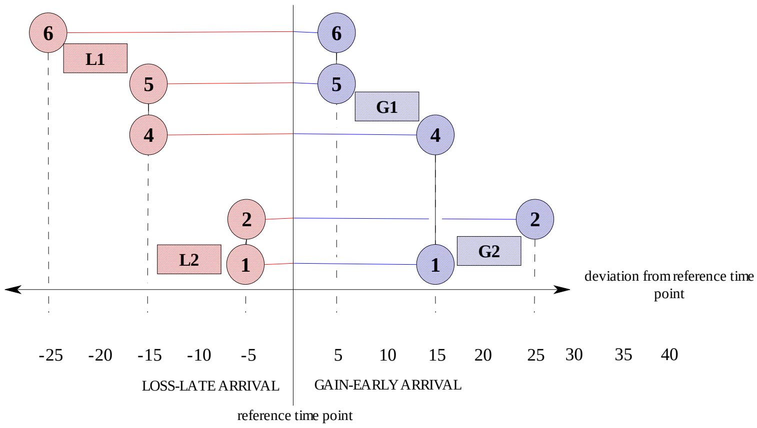

Fig. 6.

With this setting, we can derive simple inferences on the behavior of the value function in gain and loss gains. As noted above, notice that Questions 1 and 4 represent equal amounts of gain but 10 minute time difference in the losses; the same is also valid for the Questions 5 and 6, i.e., the losses are change by 10 minutes. The comparison of the paired differences between Q1-Q4 and Q5-Q6 would yield the behavior of the loss function in different regions i.e., the difference between late arrivals at 25 minutes late (Q6) and 15 minutes late (Q5)-L1 and the difference between losses at 15 minutes late (Q4) and 5 minutes late (Q1)-L2. A paired t-test reveals that the difference in WTP between two paired groups is not significantly different from zero (p=0.34), however the mean of the difference turns out to be negative. When the same analysis is applied to the gain region, where we can differentiate two patterns of gain differentials with Questions that have same amounts of losses, i.e., G1 and G2, the difference between G2 and G1 turns out to be a significant negative (p=0.00). This suggests that the gains tends to decrease in compliance with the prospect theory. Although these preliminary analyses are illuminating in ways to derive inferences for the values that accrue to the commuter by different arrival patterns, we can not say much about the WTP/WTA in detail as we disregard the variation induced by expressway. For this reason, we try to elicit alternative econometric models in the next section and with the question format it seems that it is not possible to control for the expressway arrivals while comparing for arrivals by surface streets.

Inspecting Figure 5 again, one can notice that for only two question groups (i.e., 6-7 and 3-4) expressway arrivals trace the same intervals with respect to the reference time point. Theoretically, both, question 4 should be valued more than the question 3 as increase in gain for an interval should be less than the increase in of loss of the same interval. This is supported by the data that WTP reported for the expressway increases for question 4 significantly (p=0.01) when we switch from question 3. The same inference is also verified by a simple comparison of Questions 6 and 7. Paired t-test verifies that reported WTP for question 7 is significantly higher that the one for question 6 (p=0.05).

On the other hand, the reason why the reported WTP does not reach the current toll value might be behavioral reflex that cause the reported WTP stay at level significantly below than the real WTP. The difference between the real or latent WTP and the reported or observed WTP might be termed as concealed value that might be spent in the case when the same situation is met in the real life. In other words, the concealed value might the result of the nature of the experiment as it depends on the stated preferences. We will handle the concealed value by using Frontier analysis in the next section.

5. ECONOMETRIC MODELS

We present several econometric models that try to capture the essence of either WTP or WTA phenomenon from different perspectives given the previous section. The repeated experiments can be treated as panels; consequently, the estimations have been conducted using estimation routines relevant for panel estimation with random effects. Dependent variables, in all of the regressions, are either WTP or the natural logarithm of WTP (logWTP), which is assumed to be the willingness-to-pay to switch from surface street to the expressway (Table 3). With these dependent variables, we divide the models into two groups. The first group of models, more or less, complies with the general models that have been employed in general WTP studies for open-ended responds. In this groups we use multiple regression and log-linear regression models[9]. The second group of models employs a stochastic frontier models to locate the hypothesis that there is a concealed amount between the reported WTP and the real WTP. For the second group, we devise models based on the stochastic frontier regressions. The following is the list of the dependent and independent variables that are used in the regression analyses.

Table 3 List of Variables Used in The Regression Analyses

Code	Definition	Mean	Std. Dev.
WTP	Willingness-to-pay	594.37	333.40
logWTP	Natural logarithm of WTP	6.25	0.53
GROUP	Group specific DUMMY variable, 1 stands for everyday users, 0 for two to three times per week users.	0.56	0.50
SEX	Gender specific DUMMY variable, 1 stands for males, 0 for females.	0.86	0.35
AGE	Age	47.44	11.44
LOG_AGE	Natural logarithm of AGE of the respondent	3.82	0.25
DUMMY_E1	DUMMY variable for Question 1, 1 stands for Question 1	0.14	0.35
DUMMY_E2	DUMMY variable for Question 2, 1 stands for Question 2		
DUMMY_E3	DUMMY variable for Question 3, 1 stands for Question 3		
DUMMY_E4	DUMMY variable for Question 4, 1 stands for Question 4		
DUMMY_E5	DUMMY variable for Question 5, 1 stands for Question 5		
DUMMY_E6	DUMMY variable for Question 6, 1 stands for Question 6		
DUMMY_R1	DUMMY variable for expressway arrival at the latest 5 minutes earlier than the surface street arrival at the earliest	0.42	0.49
COUPLING	Coupling time (the respondent is presented with a situation that she has to report at the destination at COUPLING minutes after at most)	63.54	6.92
LOG_COUPLING	Natural logarithm of the COUPLING time	4.15	0.11
LOSS	Time interval that falls in the LOSS region when the surface street is taken	13.61	6.92
LOSS_SQ	Square of the LOSS variable	233.14	202.23
RATIO_GL	Ratio of Gains to Losses	2.46	3.46

The independent variables are considered in two groups: the first group of variables is a collection of three individual specific variables, these are sex, age and commuter grouping of the respondent; the

[9] See Kealy and Turner, 1993; McFadden, 1994 for different specifications.

second group of variables captures the experiment by experiment specific dummy variables and the variables that characterize these experiments.

As mentioned above, we use two regression models under the first group. In this regard, we firstly use linear regression model by regressing WTP over independent variables using random effects. The regression and its estimation is straightforward and will not be reproduced here (see Greene, 2003). The second regression model is a log-linear regression which has an original functional form as:

$$WTP = \left(\prod_i X_i^{\alpha_i} \right) \exp(\boldsymbol{\beta}\mathbf{D}) \exp(\varepsilon)$$

where X represents continuous variables and **D** represents the vector of categorical or ordinal variables, ε is a linear function of error terms. The natural logarithm transformation of this functional form produces a log-linear model, estimation of which is also well established and straightforward (see Greene, 2003). We estimate the parameter values of the first group of variables by using LIMDEP econometric models estimation software package (Econometrics Software, 2002). With this first group of regressions, we maintain the general theory by assuming that reported amounts as WTP.

The second group of models consists of models based on the stochastic frontier model and Tobit models. In line with the discussion given in Sections three and four where we have presented our arguments on WTP and WTA in the context of economical theory and the experiments used in this study. Accordingly, we propose a stochastic frontier model, which treats the real WTP as an unobserved amount of money and the reported amounts are below the real WTP by a concealed value, which is captured by the inefficiency error term in the stochastic frontier model. We estimate this model by assuming random effects throughout the questions. Secondly, we set the real WTP for the expressway as 75th percentile reported for the Q7 which is same as the current toll charge, ¥700 and 90th percentile reported for the Q7, ¥1000. Having established the real WTP, we hypothesize that the values reported for the other questions should be below these capacity values. Disregarding values reported above these values, we use Tobit regression model that us censored from above. Blow is a short introduction to the two models used in the study.

Theoretically, the stochastic frontier stems from an approach that amounts to specifying the relationship between output and input levels and using two error terms, generally used in industrial (in)efficiency studies. In the model, one error term is the traditional normal error term in which the mean is zero and the variance is constant, i.e., $v \sim N(0, \sigma^2_v)$. The other error term represents technical inefficiency term (or concealment term) in our case and is generally expressed by half-normal, truncated normal, exponential, or two-parameter gamma distributions. The half normal model states that the absolute value of inefficiency term is distributed as normal with a constant variance, σ^2_u. Mean value of the inefficiency term can be assumed to be either equal to zero or a mean conditional on certain observables as Battese and Coelli (1988) proposes. The basic equation for a stochastic production frontier given by Aigner et al. (1977) can be expressed as:

$$\log WTP_{it} = \boldsymbol{\beta}'\mathbf{X}_{it} + v_{it} - u_i$$

where subscripts i and t represents individual and the time period of observation respectively; $\boldsymbol{\beta}$ and **X** are vectors of parameters and independent variables; the random error terms v_{it} and u_i are generic error term for individual i at time t (out of T_i)and time invariant inefficiency term for individual i. In this formulation, the absolute value of u_i is distributed as Normal, i.e., Half-Normal, with parameters $(0, \sigma^2_u)$. In the Appendix, we supply the distributions of the error terms along with the log-likelihood function that is used in the estimation.

Tobit regression is a natural extension of probit model and obtained by using a continuous dependent variable. In the model, as noted above, the latent variable is assumed to be observed by the capacity value, that is set to 75th (i.e., ¥700) and 90th (i.e., ¥1000) percentiles of the responds given to the pure loss question, Q7. Thus we formulate the tobit regression as follows:

Define

$$\log WTP_i = \begin{cases} \boldsymbol{\beta}'\mathbf{X}_{it} + v_{it} + u_i & \text{if } \log WTP_i^* < \log A \\ \log A & \text{if } \log WTP_i^* \geq \log A \end{cases}$$, where A is set to either ¥700 or ¥1000.

This formulation lead us to the Tobit formulation equal to logWTP_i= min (A, $\boldsymbol{\beta}'\mathbf{X}_{it} + v_{it} + u_i$). The idiosyncratic error terms are decomposed into time variant individual error term, v, which is uncorrelated across time periods t (out of T_i) and time invariant individual error term, u. These error terms are assumed to be uncorrelated with each other. With these, the log-likelihood function of the Tobit regression model is given in the Appendix. The models that are proposed under the second group are estimated by using LIMDEP econometric models estimation software too.

The estimation results of the first group of regression are presented in Table 4. The results suggest that the log-linear model performs better than the multiple regression model; besides the models which include the dummy variables for questions perform better than the models which include characteristics of the questions. Dummy variable multiple regression model suggests that women drivers at most would like to pay for the expressway service at around ¥753. This amount decreases by approximately ¥74 in the dummy variable log-linear regression model. The multiple and log-linear models, which include characteristics of questions instead of dummy variables yield results generally with insignificant coefficient values. However the log-linear model yields an upper-most value for the WTP which is at around ¥1881, this amount naturally decreases with the minus coefficient values for males, logarithm of age, logarithm of coupling time and the dummy for 5 minute interval between latest arrival possible by the expressway and the earliest arrival possible by the surface streets. Notice that as expressway and surface streets approach to each other on their extremes, this tends to affect the WTP downward. On the other hand, magnitude of LOSS tends to increase the reported WTP by either of its absolute value or logarithm transformed value. Also note that the coefficient values of logarithm transformed variables in the log-linear regression model stands for the elasticity of WTP. In this regard, the log-linear model suggests positive loss elasticity of WTP; on the other hand, we find negative elasticity of coupling time of WTP.

Table 4 Estimation Results of Multiple and Loglinear Regression Models

Independent variable and Model Fit	**Model**: Multiple regression with random effects		**Mode**l: Multiple regression with random effects		**Model**: Loglinear with random effects		**Model**: Loglinear with random effects	
	Coefficient	t-score	Coefficient	t-score	Coefficient	t-score	Coefficient	t-score
CONSTANT	753.19	13.42	-1132.15	0.98	6.52	72.69	7.54	2.10
GROUP	35.31	1.90	35.31	-1.90	0.04	1.65	0.05	1.69
SEX	-98.84	-3.75	-98.84	-3.75	-0.20	-4.73	-0.19	-4.75
AGE	-0.80	-0.97	-0.80	-0.97				
LOG_AGE					-0.01	-1.00	-0.03	-0.56
DUMMY_E1	-91.36	-2.69			-0.15	-2.74		
DUMMY_E2	-93.07	-2.74			-0.15	-2.73		
DUMMY_E3	-88.44	-2.60			-0.13	-2.50		
DUMMY_E4	-67.79	-2.00			-0.10	-1.81		
DUMMY_E5	-42.43	-1.25			-0.06	-1.10		
DUMMY_E6	-25.85	-0.76			-0.01	-1.00		
DUMMY_R1			-31.40	-0.03			-0.03	-0.37
LOG_COUPLING							-0.32	-0.43
LOSS			13.64	0.07				
LOSS_SQ			-0.25	-0.80				
LOG_LOSS							0.10	0.59
RATIO_GL			10.07	0.29			0.01	0.84
Restricted Log-likelihood	-9601.71				-1072.11			
Log-likelihood	-9538.27		-9538.48		-999.62		-1000.25	
Sample size	225							
d.f.	30		29		30		28	

The models that are estimated by the second group of regression models are carriers of the hypothesis that the reported WTP is either as a result of concealment or the result of a capacity that an individual can pay in various degrees of risk. By this, we significantly divert from the general WTP studies based on open-ended questions. The results of three models, one by the stochastic frontier model and two by the Tobit model regression are presented in Table 5. Note that in both of the stochastic frontier model and the Tobit models, the dependent variable is taken as the logarithm of WTP as same in the log-linear regressions in the first group of regressions. Accordingly, we have used transformed values for the upper limits used in the Tobit regressions, i.e., 700→6.55 and 1000→6.91.

Table 5 Estimation Results of Stochastic Frontier and Tobit Models

Independent variable and Model Fit	**Model**: The stochastic frontier regression model		**Model**: The stochastic frontier regression model		**Model**: The tobit regression		**Model**: The tobit regression	
	Coefficient	t-score	Coefficient	t-score	Coefficient	t-score	Coefficient	t-score
CONSTANT	6.75	132.52	7.06	2.69	6.29	36.30	6.61	54.08
GROUP	0.07	2.53	0.15	4.67	-0.05	-2.25	-0.04	-2.03
SEX	-0.00	-0.09	-0.06	-0.83	-0.03	-0.83	-0.02	-0.86
LOG_AGE	0.00	0.17	0.28	1.68	0.08	1.83	-0.02	-0.86
DUMMY_E1	-0.14	-3.00			-0.18	-4.10	-0.15	-4.67
DUMMY_E2	-0.15	-3.11			-0.18	-4.19	-0.15	-4.76
DUMMY_E3	-0.13	-2.72			-0.15	-3.47	-0.13	-3.96
DUMMY_E4	-0.10	-2.02			-0.11	-2.34	-0.09	-2.80
DUMMY_E5	-0.05	-1.11			-0.07	-1.25	-0.06	-1.40
DUMMY_E6	-0.02	-0.33			0.01	0.17	-0.19	-0.17
DUMMY_R1			-0.03	-0.56				
LOG_COUPLING			-0.30	-0.57				
LOSS								
LOSS_SQ								
LOG_LOSS			0.13	0.81				
RATIO_GL			0.01	1.28				
λ	1.41	9.50	5.11	4.81				
σ_u	0.68	31.35	1.17	11.14	0.26	93.15	0.23	131.89
σ_v					0.46	45.60	0.37	62.50
Restricted Log-likelihood	-1168.80		-1169.03		-1157.61			
Log-likelihood	-299.93		-300.81		-490.31		-261.43	
Sample size	225							

A quick comparison of the model estimations presented in Table 5 suggest that the best model in the second group of regressions is the tobit model which takes the ¥1000 as its upper boundary. The models that locate dummy variables for questions yield constant values that range between ¥540 (the tobit model with ¥700 upper limit) and ¥854 (the stochastic frontier model). For the tobit model results, a general diversion from other models is observed in the group dummy variable that in both of the tobit models the coefficient of this variable turns out to be negative. A general result from all of the models is that the WTP increases from Question 1 to Question 7. Although increasing value of loss either in absolute or logarithm transformed magnitudes suggests high WTP, the coefficients are insignificant.

6. CONCLUSIONS

It has been shown, however not fully but partially, that the prospect theory offers a base for route choices as the differences in gain and loss have significant reflections in reported WTP. Besides, the gains at different distances from a reference time point display increase decreasingly with reported WTP. The losses are significantly higher that the gains for similar distances from the reference time point. Generally, it has been shown that risk inherent on the surface streets directly affects the use of expressway. An important caveat is that the risk is not viewed as the travel time variation simply, but rather as a combination of the travel time variation and the coupling time point, which is translated as a reference time point into our research.

We derive two general conclusions from the regression analyses: the first one is that WTP for expressway structurally changes with the risk level on the surface streets, and the second one is that reported WTP (in a stated preference study) might be below than the real WTP by a certain amount (which we call as concealment value). The first one is generally captured by all of the regression analyses presented, but especially by the Tobit regression model. In the regression analysis, it has been shown that the risk levels inherent in the questions display significant relations to WTP; generally the results suggest that as the risk level increases WTP also increases. Besides, in the Tobit regression model, we have found that 90th percentile of the responds reported for the pure loss question, i.e., Q7, sets the approximate capacity value for WTP as the Tobit model that uses this capacity value achieves the best log-likelihood among similar models. Referring to previous sections, this capacity might be termed as WTA, which might be the EV in the context of welfare gain represented by a route change from a surface street to expressway. The second result has been derived from the results obtained by the frontier regression models. Generally, these models suggest that there is a concealment value in the reported responses. We believe that individuals are apt to report values below the real value that can be paid; because they might feel themselves more comfortable by leaving a gap that might be traversed in the case of increased risk, and they might gradually increase the value or suddenly switch to the real WTP when their reported values turns out to be of no use. In terms of future research, we conclude that complex and flexible models to locate different concealments in different settings and an explicit frontiers are needed. In this regard, an explicit frontier might be associated with the responds given to the alternative that bears the most loss or pure loss.

APPENDIX

The log-likelihood function have been elicited from studies of Pitt and Lee (1981), Batisse and Coelle (1988) and Econometric Software (2002). The density functions of u and v can be given as

$$f_v(v) = \frac{\exp\left(-\frac{1}{2}\frac{v^2}{\sigma_v^2}\right)}{\sqrt{2\pi}\sigma_v} \text{ and } f_u(u) = \frac{f(u)}{F(u \geq 0)} = \frac{\exp\left(-\frac{1}{2}\frac{u^2}{\sigma_u^2}\right)}{\sqrt{2\pi}\sigma_u \Phi(0)}$$

Let $\varepsilon_{it} = v_{it} - |u_i| \equiv \log WTP_{it} - \boldsymbol{\beta}'\mathbf{X}_{it}$, $\lambda = \sigma_u/\sigma_v$, and $\sigma^2 = \sigma^2_v + \sigma^2_u$ and define $\gamma = \lambda^2$, $A_i = 1 + \gamma T_i$, $\mu_i = (1/Ti)\Sigma\varepsilon_i$, and $h_i = (\gamma T i \mu_i)/(\sigma_u A_i)$. The log-likelihood function for one observation becomes:

$$\log \ell_i = -\left(\frac{T_i}{2}\right)\log(\pi) - T_i \log(\sigma_u) - \frac{1}{2}\log(A_i) - \frac{T_i}{2}\log\gamma - \frac{1}{2}\frac{\gamma}{\sigma_u^2}\sum_{i=1}^{T_i}\varepsilon_{it}^2 + \frac{1}{2}A_i h_i^2 + \frac{1}{2}\log\Phi\left(h_i\sqrt{A_i}\right)$$

For the derivation of the log-likelihood function for the Tobit regression model, we have made use of studies Amemiya (1981), Maddala (1986) and Econometric Software (2002). Both of the error terms are distributed as iid Normal with zero mean and σ^2_v and σ^2_u. The probability of log*WTP* changes when it is censored and it is not. When it is censored to value log*A*, the probability becomes

$$f^c(\log WTP|u_i) = \Pr\left[\log WTP^* \geq \log A|u_i\right] = 1 - \Phi\left(\frac{\log A - \boldsymbol{\beta}'\mathbf{X}}{\sigma_v}\right),$$

This function changes when log*WTP* is not censored,

$$f^{uc}(\log WTP|u_i) = \frac{1}{\sigma_v}\phi\left(\frac{\log WTP - \boldsymbol{\beta}'\mathbf{X} - u_i}{\sigma_v}\right)$$

With these probabilities, probability of an observation at a certain time becomes

$$f\left(\log WTP|u_i\right)=\left[f^{c}\left(\log WTP|u_i\right)\right]^{1-d_{it}}\times\left[f^{uc}\left(\log WTP|u_i\right)\right]^{d_{it}}$$

where d is equal to zero when the observation is censored and 1 when it is not.

Likelihood of an observation per individual can be given as

$$\ell=\prod_{t=1}^{T_i}\int_{-\infty}^{+\infty}f\left(\mathbf{y_i}|u_i\right)g\left(u_i\right)du_i$$

Notice that the function, g is the distribution function of the individual error term u with zero mean and fixed variance, σ^2_u. The function and its derivatives are evaluated by Hermite quadrature techniques.

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