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Road Safety Valuation under a

Stated Choice Framework

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ABSTRACT: The value of fatal risk reductions is a vital input for road safety cost-benefit analysis. It has been traditionally estimated by means of contingent valuation in spite of growing criticism surrounding this approach. Furthermore, many believe that risk-money trade-offs are not well understood due to the difficulty in internalizing tiny risks. We have succeeded in applying the Stated Choice (SC) approach to tackle this problem, using as one of the attributes the number of accidents with fatal victims (i.e. a proxy for risk). To assess the robustness of SC, we conducted an external validity test based on results for three different studies. We investigated if preferences were well defined according to economic theory (i.e. as initial risk increases, the marginal willingness-to-pay should be higher). We also addressed the generally ignored issue of whether there should be a unique value of fatal risk reductions.

We found that people can internalize risk consistently from an economic viewpoint, and that although each sample yields different values of risk reductions, there was a relationship between the risk level and the value of risk reductions in each context examined; this evidence could be most helpful within the context of developing countries. Finally, we offer an hypothesis to explain the differences between our values with those obtained in industrialised countries, highlighting the importance of doing local studies rather than transferring imported values.

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1. Introduction

The value of road safety has been estimated traditionally by means of contingent valuation, standard gamble or the chain method (Viscusi *et al*, 1991; Jones Lee *et al,* 1993; Beattie *et al,* 1998; Carthy *et al,* 1998), but the approach, in general, has been heavily criticized by specialists in human behaviour (Fischoff, 1991; 1997) and in the econometric profession (Hausman, 1993; Diamond and Haussman, 1994). Furthermore, in all the above cases people have been confronted with situations expressing risks as tiny probabilities, and involving a trade-off between risk and money to come up with a monetary value[1]. This kind of context simulation may not bear upon actual choices where individuals have to consider a bundle of attributes of a particular good in a given choice context.

A different approach, used recently by Rizzi and Ortúzar (2003) and Iragüen and Ortúzar (2003), and followed by de Blaeij *et al* (2002), is based on Stated Choice (SC) or conjoint analysis techniques and is free of most of the criticisms mentioned above. A SC survey asks individuals to choose among different alternatives, the attribute levels of which vary according to a statistical design aimed at maximizing the precision of the estimates. SC allows the analyst to characterize the choice situation context with high precision so that it can mimic actual choices with a high degree of realism.

Rizzi and Ortúzar (2003) defined a particular kind of trip on a particular road for two reasons. First, the choice context must be replicated accurately to derive meaningful results (Ampt e*t al*; 2000, Louviere *et al*, 2000). Second, from a theoretical point of view different risks may be valued differently because of different risk perceptions. Dread, knowledge of risks and personal benefits from exposure, are all factors contributing to risk perception and eventually to different Willingness to Pay (WTP) for reducing it (Slovic *et al*, 1985). Hence, it is crucial to define a specific risk context. For example, recent research has demonstrated that private motoring is a risk well understood by most people in Santiago de Chile: it is under their control and yields great personal benefit (Bronfman and Cifuentes, 2003).

As another feature, instead of providing a probability of fatal risk for each alternative we decided to use the number of fatal accidents as a risk proxy. Jones Lee *et al* (1993), Krupnik *et al* (1997) and O'Brien *et al* (1998) provide enough evidence of people having difficulties in dealing with probabilities. In a contingent valuation survey conducted by the latter, many people were unable to tell that an event with a probability of one in a hundred (1/100) was more likely to occur than an event with a probability of 1 in two hundred (1/200). Based on this evidence, we decided that the level of risk should be expressed in another fashion.

Now, although SC applied to risk analysis seems promising given the excellent results we have obtained, its reliability remains to be tested. According to theory, we expect that the more risky a road context is and/or the higher the risk reduction offered, the higher should be the WTP. For this reasons, in this type of analysis an external validity test is essential. By external validity we mean confronting the results of similarly

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[1] Some of these studies posed a risk – risk trade-off. However, in order to arrive to a monetary value, a risk – money trade off is necessary sooner or later.

designed SC surveys applied to different road contexts to assess the sensitivity of WTP to the initial risk level.

In addition, we would like to treat variability in determining the Value of Risk Reduction (VRR)[2] explicitly and go one step beyond to say that cost-benefit analysis of road safety projects should incorporate it. The few countries that currently assign a VRR to safety improvements in road project appraisal use only one figure, irrespective of the level of safety of the road (Trawen *et al*, 2002). We would like to challenge this stance and show, at least methodologically, that a simple alternative works well (at least with data sets obtained from properly designed experiments).

The objective of this paper is twofold. First, we address some subtle issues concerning the way the VRR is defined for different road contexts and how this can be incorporated in a evaluation framework. Second, we investigate to what extent SC constitutes a reliable method for eliciting road safety preferences, which are not derived from people's valuation of risk reductions but from people's valuation of accident reductions. To this end, we analyze three experimental studies concerning the valuation of risk reductions in different road contexts: two interurban ones and an urban one.

The rest of the paper is organized as follows. Section 2 analyzes how the VRR is derived in the context of road safety and what sort of particular demand structure is implied by a unique VRR. Section 3 comments briefly on the three surveys that constitute our data bank and Section 4 presents the econometric analysis. Finally, Section 5 closes the paper with a discussion.

2. The Value of Fatal Risk Reductions (VRR)

Assume a route is used by *M* users. If a person travels more than once in a reference period, say n_m times, we can say that she gives rise to n_m pseudo-members totalling a population of $N = M n_m$ observations; from now on these will be called the individuals of a population. This population exactly amounts to the flow on a route in a given period (say a year)[3]. We define a route as a path connecting one origin-destination pair. A trip on a route provides a level of dissatisfaction given by the following deterministic indirect utility function *V*:

$$V = V(r, c, t) \tag{1}$$

where *r* stands for risk of a fatal accident, *c* for the cost of the route and *t* for travel time. A formal definition of the VRR is given by Jones Lee (1994): provided there is no correlation between WTP and risk, the VRR is equal to the value of avoiding one expected death and this corresponds to the population (or sample) average of the marginal rate of substitution between income and risk of death for member *j* (MRS_j):

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[2] Also termed the value of a statistical life, but we would rather avoid this term.
[3] Actually, a population is a stock variable whereas a flow is not. The reader should bear this in mind.

$$MRS_j = \frac{\partial V_j / \partial r}{\partial V_j / \partial c}\Big|_{V=\bar{V}} \quad , \tag{2}$$

$$VRR = \frac{1}{N}\sum_{j=1}^{N} MRS_j \, . \tag{3}$$

Equation (3) gives the definition of WTP for a public good, road safety in this case. The MRS can be interpreted as an implicit value for the own life and averaging it over all individuals travelling on the route yields the VRR. The MRS clearly depends on personal risk perceptions according to the functional form of equation (1). If another route is considered, flow and risk figures are likely to be different but one would expect that a relationship between risk and the MRS should follow certain patterns. For instance, one would expect that the WTP for risk reductions should increase with the risk of death and/or with the risk reduction offered, as shown in Figure 1 by the full line curve.
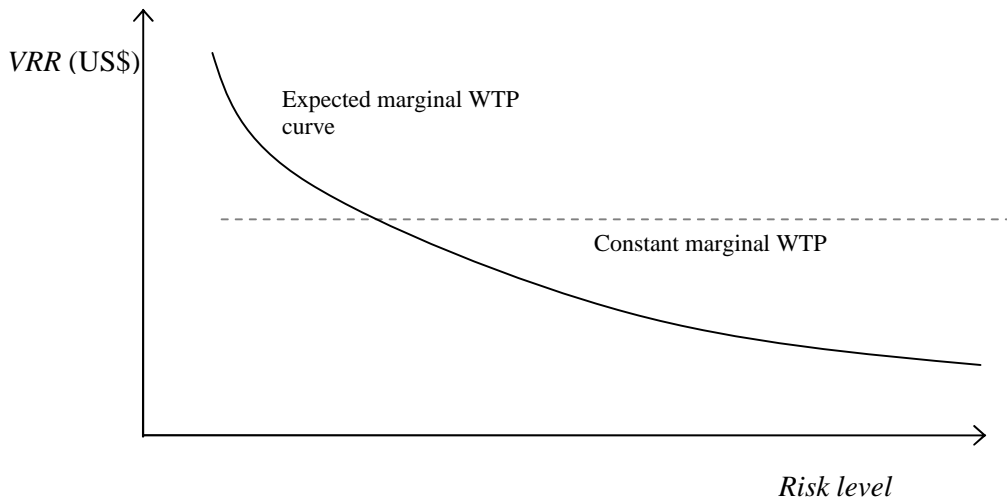

Figure 1. Expected VRR pattern as a function of initial risk

The same analysis can be carried out in terms of fatal accidents, *a*, instead of risks, *r*. However, in this case the VRR is derived differently (but yielding obviously the same value):

$$VRR = \frac{1}{e}\sum_{j=1}^{N} \frac{\partial V_j / \partial a}{\partial V_j / \partial c}\Big|_{V=\bar{V}} = \frac{1}{e}\sum_{j=1}^{N} SVAR_j \, , \tag{4}$$

This is the more traditional way to define the WTP for a public good, where *e* represents the number of fatal victims per fatal accident and the subjective value of fatal accident reductions (SVAR) is interpreted as a Lindahl price. Thinking in terms of a tolled route for example, the SVAR would be the maximum toll increase for individual *j*, due to a safety improvement, such that she is as well-off as before the improvement. In real life,

however, this value is assumed unique and can be computed as the average or the median SVAR.

The relationship between risk and WTP is less transparent when working with the SVAR. Assume one tries to determine a unique value of the VRR for every route, as done by Jones Lee *et al* (1993) and de Blaeij *et al* (2002), and wants to translate this into a SVAR. If flows vary between routes, clearly the SVAR should be different; in other words, if tolls were increased in order to finance safety improvements, the increase would vary with the route flow in a unique way: simply dividing the VRR by the flow route and multiplying by the *e* factor. Clearly, this would only be true if the value of identical risk reductions is the same, independently of the initial risk level. This is a very restrictive assumption on risk preferences, as it implies a constant marginal WTP for safety (see the horizontal dashed light grey line in Figure 1).

For cost benefit analysis, considering only one VRR for every road context may give rise to a non-optimal allocation of resources; for instance, less safer routes may be likely to suffer under-investment.

Turning now to model estimation, equation (1) can be made operational within a binary choice context in this way:

$$V_{ij} = \left(\boldsymbol{a}_0 + \sum_l \boldsymbol{a}_l s_{lj} \right) a_{ij} + \boldsymbol{b} c_{ij} + \boldsymbol{l} t_{ij} \quad (\text{i} = 1, 2) \tag{5}$$

The binary variable s_{lj} represents the socio-economic (SE) characteristic l of individual j, and i represents the choice alternative. This is an interesting way of incorporating SE variables, with the advantage that the information can be used to estimate, for instance, the SVAR. Equation (5) states that given the characteristics of the individual there may be different coefficients for each attribute. The SE variable could enter each of the three coefficient expressions.

This form of introducing SE data allows estimating models that are almost unique for each individual (Ortúzar and Willumsen, 2001, pp. 261). The VRR is computed by applying equation (4), which requires the SVAR for each individual. If SE variables are excluded, equation (5) becomes a simple linear utility function and the SVAR is just α_0/β for every individual. Also note that by computing λ/β, the subjective value of time (SVT) is obtained (Gaudry *et al*, 1989). For the rest of the paper we will use this simpler utility function.

3. The Surveys

In this section we briefly describe the surveys that provided the data for our external validity analysis. First we concentrate on the two interurban surveys, which were very close in terms of design and context, and next we move on to the urban survey which was very different in context and survey methodology. We then proceed to explain how we defined the risk variable in all three cases.

3.1 Interurban surveys

Rizzi and Ortúzar (2003) conducted a survey in order to elicit drivers' valuations of fatal accident reductions for Route 68, linking the conurbations of Santiago, Chile's capital, and Valparaíso, the country's largest port and second biggest city; this route is approximately 120 km long. The survey was responded by 342 interviewees during the austral summer 1999-2000.

In order to achieve truly realistic scenarios, after several pilots, pre-tests and focus group work conducted by a specialized psychologist, it was decided that several contexts should be created. First, there were trips from Santiago to Valparaíso and vice versa; second, some of the trips were assumed to take place on the weekend and their purpose was to attend a social meeting; other trips occurred on a regular working day for reasons of work or personal errands. With respect to trips on working days, the time of day could be either the morning or the evening. In every case the journey was assumed to be unavoidable; in other words, it had to be done, so there was no room for a *non-purchase* option (see Olsen and Swait, 1998).

With respect to the risk variable, our main problem was that although the accident figures were factual people might not have been familiar with them; however, people are indeed aware that the Santiago-Valparaíso route ranks among the safest in Chile (high police control and a reasonably competent highway design). For this reason, in the explanation of the choice experiment we decided to state that the actual number of accidents with at least one fatality during the period 1996-1997 was 12 on average. The wording of the text introducing respondents to the choice game (which was in Spanish in the survey form) for a trip that takes place at the end of a regular working day from Valparaíso to Santiago is shown below (framed and in italics) as an example. Figure 2 presents an example of the cards defining the choice situations presented.

As can be seen, the context is clearly defined: the day, time of day and trip purpose are all specified; it was assumed that the person who answered the questionnaire was the driver and she was also assumed to pay for the toll. Many motorways operate under a private toll system in Chile and a system of concessionaires is being introduced on a nation-wide basis. Thus, people are already familiar with changing toll charges and, besides, the government has informed that a likely strategy for the future is to increase toll values if the concessionaires manage to achieve certain quality improvements (ie safety related).

You are to return to Santiago after spending a regular working day in Valparaíso. The trip has the following characteristics:

- *You drive your car*
- *You pay for the total cost of the trip, including the toll*
- *You have to return after 8.00 p.m.*
- *You have to choose between two routes for your return-trip (both are similar to the current Route 68 Santiago-Valparaíso), considering the following three factors: the toll, the travel time on route and the number of fatal accidents on each route. The latter is defined as the number of accidents per year in which at least one person travelling by car dies.*

We now ask you to carefully consider the next nine choice situations; in each one of them you have to pick up one of the two possible routes for the trip to be taken. Please consider each choice situation independently of the other situations.

With reference to the number of accidents, in 1997 there were 12 accidents in which one of the car occupants died on Route 68.

Choice situation Nº __	Route 1	Route 2
Travel time	1 hour 30min	2 hours
Fatal accidents	12	20
Toll (US$)	7	5
	I choose Route 1	I choose Route 2

Figure 2: A typical card from the Route 68 Stated Choice game

Safety has the dimension of a private good, and as the choice context related to a particular trip there was little room for an altruistic choice. Therefore, we feel that it was in the best interest of the respondents to give a truthful answer. This way we managed to increase the "realism" of the hypothetical choice context to a plausible maximum, reducing the possibility of strategic bias to the greatest degree.

During the austral autumn of 2000, another survey of almost identical characteristics was designed (taking advantage of the good experience with the previous survey) and administered to a random sample of drivers on a 100 km section of Route 5 by a group of graduate students at the Department under our supervision (Galilea *et al*, 2000). Route 5 is a stretch of the Pan American Highway linking Santiago and Rancagua, the fifth largest city in the country and the gateway to the south of Chile. This second survey was answered by 94 respondents. Once more, individuals were presented with several hypothetical situations where they had to choose among two different routes (binary choice).

The experimental design was the same in both cases and although there were changes in the levels of the route choice attributes their differences were exactly the same, as shown in Table 1.

Table 1. Attribute differences levels

Week-end toll (US$)	Week-day toll (US$)	Fatal accidents per year	Travel time (min)
3.0	2.4	-4	-30
-2.0	-1.6	8	-15
1.0	0.8	-12	-45

Of the three variables considered: toll value, number of fatal accidents, and en-route travel time, Route 5 had a higher number of accidents and lesser travel time than Route 68[4]. Toll levels were identical, the only difference being if it was a week-end or a week-day toll.

Both samples are similar in terms of three basic socio-economic variables: income, gender and age. Family income was remarkably the same (no differences at the 0.05 level) as these are samples of basically high income individuals (the reader should bear in mind that car ownership in Chile is highly correlated with income). Women account for 29% and 30% of the respondents in Route 5 and Route 68 respectively, the difference not being statistically different at the 0.05 level. We only found differences in the age profile of the samples; the Route 5 sample included a greater proportion of individuals under 30 and a lesser one of individuals among 30 and 49. But all in all, from these results we believe that it is certainly possible to consider both samples as coming roughly from the same population.

3.2 Urban survey

Iragüen and Ortúzar (2003) conducted a third survey in the 2002 austral autumn in order to come up with the VRR for work related trips in an urban road context. The statistical design was exactly the same as before, but the attribute levels were adapted to the type of trips under consideration (the survey format can be seen at www.ing.puc.cl/~piraguen). Also, this survey was conducted by the internet and answered directly in the web-page (by more than 300 individuals), so it is a different kind of bird. In general the proportion of both females and young respondents was high in comparison with the two other surveys but income was roughly the same. We will see later what kind of bias this may introduce in terms of the VRR.

3.3 The definition of the risk variable

We now turn to explain why we decided to use the number of fatal accidents as a proxy for the risk of death in our surveys. The main reason is that we do not believe that people consider risk as an objective probability (i.e. as derived by the safety engineer), but as an entity which is the result of complex mental processes where risk perceptions and risk attitudes play an important role. Most people develop an idea about the level of safety of a given route through their personal risk perception when driving and through

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[4] There were approximately 12 and 36 annual accidents on Route 68 and Route 5 respectively; the average travel time for Route 68 was one hour and thirty minutes and for the Route 5 section considered it was just over an hour.

information mostly coming from the media. When there is a road crash the information on the media is stated in terms of number of accidents, number of fatalities, number of seriously injured victims and so on. Besides, the frequency with which a certain road is involved in accidents helps to get an idea of how dangerous it is. For these reasons, we only interviewed people that stated having used the routes in question at least once during the last year. During our focus group work we came to learn that otherwise the context of fear associated to the risk of an accident could have vanished from the individual mind.

Of course, we do not pretend to say that people keep mental accounts of the number of accidents on each route they (may) travel. However, we strongly believe that if they care about safety, the idea of "how much safe a route is" is derived from the above facts and not from probabilities of accidents. Following the finding of Bronfman and Cifuentes (2003), that private motoring is perceived as a well understood risk, we believe that a road accident is a familiar concept and, therefore, we argue that most people may have already arrived to some sort of well defined and stable preferences about this concept (Nash, 1990). Thus we decided to use the number of fatal accidents as a risk-proxy variable, and this proved satisfactory in practice. Our modelling results should yield plausible values for small changes in the risk level of a route environment; and not at all for major changes in road safety.

4. Modelling Results

In this section we present the results of our econometric analysis. First we consider jointly the two interurban surveys (Rizzi and Ortúzar, 2003; Galilea *et al*, 2000) due to their high similarity. We tried a variety of model specifications and also considered unobserved heterogeneity. In a second stage we incorporated the data set collected by Iragüen and Ortúzar (2003).

The outcome of these analyses provides the basis for our external validity test. Ideally, the same individuals should have been subject to the different SC surveys in order to carry out this test, but this was impossible. Hence, our external validity test will consist in analyzing how the VRR varies according to different risk levels in different samples. Notwithstanding, this is still a stringent test and the results were quite interesting as we will see below.

4.1 Interurban road safety models

To have an idea of the approximate magnitudes of risk for both routes, let us indicate that the flows using Route 68 and Route 5 are of the order of 3 700 000 and 5 785 000 vehicles/year respectively; the number of accidents between 1998-2000 averaged 11.3 and 35.6 respectively. Finally, the average number of deaths per accident was 1.66 and 1.30 for routes 68 and 5.

4.1.1 Traditional estimation

Binary logit models were first estimated using the data from these two surveys separately, assuming that each individual observation was uncorrelated with the other observations coming from the same individual. This is the traditional way SC data is modelled in practice (Louviere *et al*, 2000). The results are shown in Table 2; the

combined log likelihood is the sum of the log likelihood values of the models for each sample (Ortúzar and Willumsen, 2001, pp 257-270).

From this model we can see that the point estimates for both the subjective value of accident reductions (SVAR) as well as for the value of risk reductions (VRR) are higher for Route 5. Following Armstrong *et al* (2000) we computed the 95% confidence interval for both the SVAR and the VRR. The former ranges from 0.236 to 0.338 US$/accident for Route 68, and for Route 5 from 0.242 to 0.652. Interestingly, this last interval almost completely includes the first one.

Table 2. Separate binary logit models

Parameters	Route 68	Route 5	Parameter Ratios
Toll (10^{-3} Ch$)*	-0.7449	-0.62695	1.188
Travel time (10^{-1}min)*	-0.3908	-0.4780	0.818
Accidents*	-0.1027	-0.1054	0.974
SVT (US$/hr)	6.24	9.12	-
SVAR (US$/acc)	0.276	0.336	-
VRR (US$/risk)	612 146	1 491 168	-
Combined log-likelihood		-2244.73	-

* All estimated values are significant at p=0.05. In 2000, 1US$ equalled Ch$ 500

However, if we now turn to the VRR we obtain the following intervals expressed in US$/risk [522 726; 750 430] for Route 68 and [1 075 307; 2 897 026] for Route 5. Clearly, this time both intervals do not overlap at all.

We now want to examine if the VRR complies with the expected *a priori* pattern. The risks of death in routes 68 and 5 are respectively $5.09 \cdot 10^{-6}$ and $8.02 \cdot 10^{-6}$, whereas the magnitudes of the risk reductions brought about by one less expected death are respectively $4.5 \cdot 10^{-7}$ and $2.25 \cdot 10^{-7}$. Figure 3 illustrates the shape of the marginal WTP curve for risk reductions associated with these results. A pattern that seems quite plausible emerges: the value of fatal risk reductions depends not only on the value of the risk reduction offered but also on the initial risk level. The shaded areas in light and heavy grey represent the SVAR for routes 68 and 5 respectively: note that SVAR is the VRR times the magnitude of risk reduction. This shows diagrammatically how the two concepts interact.
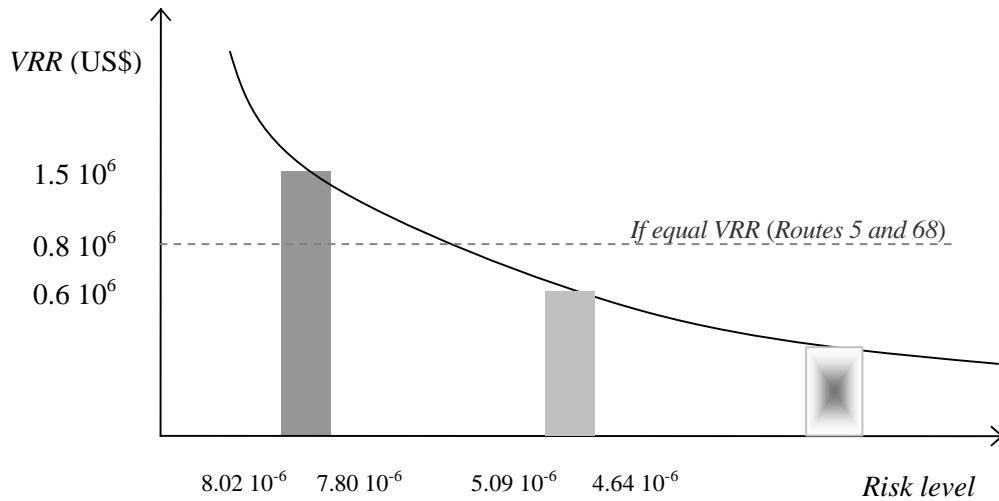
Figure 3: Implied VRR curve from our three data sets (un-scaled values).

We also ran a model forcing the value of risk reduction to be identical across both routes, yielding a value of US$ 759 837 and values of time of 7.08 and 9.60 US$/hr respectively, for routes 68 and 5. Under this assumption, the marginal WTP curve for risk reductions should be horizontal (the dashed light grey line in Figure 3) and equal risk reductions would be equally valued, independently of the initial risk level. This last VRR would imply SVARs of 0.342 and 0.17 US$/accident for routes 68 and 5 respectively. Note that as this model implies a constant marginal WTP for safety the SVAR is higher in Route 68 because it entails a higher risk reduction: as one expected death is avoided on each route, the risk reduction will naturally be higher the lowest the flow in the route is (also adjusting by the *e* factor).

The reader should note that these last values are not supported by the models in Table 2. The log-likelihood of this restricted model amounts to 2262.76, indicating that it is statistically inferior to the model presented in Table 2 (likelihood ratio test of 36.07 for two degrees of freedom against the critical value of $\chi^2_{2;\ 0.95} = 7.81$), so it should be discarded (Ortúzar and Willumsen, 2001).

We also wished to investigate if the SVAR was stable across both samples. To accomplish this we first tested the hypothesis of equal taste parameters for both surveys constraining them to be the same (the results are shown in column two of Table 3). If we perform a likelihood-ratio test, we can reject the null hypothesis of equal parameters with confidence (17.63 for three degrees of freedom against the critical value $\chi^2_{3;\ 0.95} = 5.99$)[5].

Then we examined the more sensible hypothesis of equal parameters but different scale values. The difference in this case is directly related to the error variances in both samples; the lower the scale parameter the higher the variance for Gumbel distributions. For a logit model the probability of choosing option *i* is given by the following formula:

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[5] Even at the p=0.005 level it would be rejected.

$$\text{Prob}(i) = \frac{e^{\mu V_i}}{\displaystyle\sum_l e^{\mu V_l}}$$

(6)

where μ is the scale parameter. As this parameter can not be identified it is normalized (i.e. assumed equal to one). However, when two different samples are considered the ratio μ_1/μ_2 can be estimated as only one parameter needs to be normalized (see the discussion in Carrasco and Ortúzar, 2002); in our case we selected μ_2 corresponding to the Route 5 sample. If the parameter ratio is higher than one, it implies that the variance of the first sample is lower than the variance of the second survey and vice versa (Louviere *et al*, 2000).

Table 3. Binary logit models testing for equality of parameters

Parameters	Route 68 - Route 5 Equal parameters and scale	Route 68 - Route 5 Equal parameters, different scale
Toll (10⁻³Ch$)*	-0.6961	-0.8802
Travel time (10⁻¹min)*	-0.4024	-0.5141
Accidents*	-0.1018	-0.1285
SVT (US$/hr)	6.94	7.01
SVAR (US$/acc)	0.292	0.292
VRR (US$/risk)	649 320 - 1 297 867	648 193 - 1 295 614
Scale factor (μ_1/μ_2)	-	0.7351**
Log-likelihood	-2253.54	-2247.79

* All estimated values are significant at p=0.05.
**Statistically different from one (1) at p=0.05

Different variances could be attributed to various reasons. First, there could be an unobservable context whose influence is percolated through the scale parameter. Second, as the survey for Route 68 was answered by more individuals it is reasonable to expect higher precision. However, if we have a look at the parameter ratios in Table 2, we can see that whilst the first ratio is greater than one, the other two are less than one; this led us to believe that the hypothesis of equal parameters and different scale should also be rejected and it was indeed (6.13 for two degrees of freedom against a critical value of $\chi^2_{2;\,0.95} = 5.99$). The value of the scale factor in Table 3 does not lend support to our *a priori* ideas; apparently there is more variance in the Route 68 survey.

Having discarded parameter equality, we decided to examine the potential equality of only one of the parameters defining a specification which statistically was equal to that of Table 2; this assumes equal risk parameters (see Table 4) by restricting the accident coefficient to be the same in both surveys. This specification yields a model statistically equivalent to the first one (0.028 against $\chi^2_{2;\,0.95} = 5.99$); although we intuitively expected exactly the opposite (i.e. more stable toll or travel time parameters rather than

that for accidents[6]), results are very similar to those shown in Table 2 when considering both the SVAR and the VRR.

Table 4. Models with equal risk parameter

Parameters	Route 68	Route 5	Parameter Ratios
Toll (10^{-3}Ch$)*	-0.7499	-0.6059	1.238
Travel time (10^{-1}min)*	-0.392	-0.472	0.831
Accidents*	-0.1032	-0.1032	1.000
SVT (US$/hr)	6.24	9.36	-
SVAR (US$/acc)	0.276	0.340	-
VRR (US$/risk)	611 025	1 511 585	-
Combined log-likelihood		-2244.74	-

* All estimated values are significant at p=0.05

We finally computed confidence intervals for the models in Table 4. First, the 95% confidence interval in US$/accident for the SVAR on routes 68 and 5 are respectively [0.236; 0.336] and [0.244; 0.58]. Once again, the second interval almost completely contains the first one. However, if we consider the VRR the 95% confidence intervals in US$/risk turned to be [518 796; 752 821] for Route 68 and [966 002; 3 422 446] for Route 5, not overlapping at all. The confidence interval for the Route 5 model is now wider in relation to that of the models in Table 2, but it does still not overlap with the interval for Route 68.

4.1.2 Contemporary estimation

So far our models have not allowed for unobserved heterogeneity among different individuals. Heterogeneity arises from the fact that as each respondent answered nine choice situations, her answers are likely to be correlated. When this fact is taken into account fits usually improve dramatically. Unobserved heterogeneity was modelled using uniformly distributed random taste parameters (α_0, β and ? in equation 1) within a Mixed Logit framework (Train, 2003). Table 5 shows the results. The VRR is now somewhat higher for both samples, especially for Route 68, but still within the confidence intervals associated to the models in Table 2 and Table 4.

4.2 Urban road safety model

We now turn to examine the results of Iragüen and Ortúzar (2003) for the avoidance of fatal accidents in urban areas (Table 6). The risk magnitudes are in the order of $1.85 \cdot 10^{-6}$ and the risk reductions of $3.09 \cdot 10^{-7}$ in this case (as expected, urban streets are safer than interurban roads).

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[6] We thought that time and money perceptions could be route-independent, whereas fatal risk would not.

Table 5. Mixed logit models

Parameters	Route 68	Route 5
Toll (10^{-3}Ch$)*	-0.0239	-0.0166
Std. dev. (10^{-2}Ch$)*	0.4499	0.3212
Travel time (min) *	-0.1191	-0.1186
Std. dev. (min)*	0.1361	0.1221
Accidents*	-0.3617	-0.2828
Std. dev.*	0.57	0.4234
SVT (US$/hr)	6.00	8.64
SVAR (US$/acc)	0.302	0.342
VRR (US$/risk)	671 909	1 516 690
Combined log-likelihood	-1608,97	

*All values significant at p=0.05.

Table 6. Results for the urban case

Parameters	Logit Model	Mixed Logit Model
Cost (10^{-2}Ch$)*	-0.304	-1.190
Std. Dev. (10^{-1}Ch$)*	-	0.107
Travel time (10^{-1}min)*	-0.1307	-4.047
Std. Dev.(10^{-1}min)*	-	2.582
Accidents*	-0.1468	-0.5973
Std. Dev.*	-	0.576
SVT (US$/hr)	4.80	3.80
SVAR (US$/acc)	0.089	0.093
VRR (US$/risk)	290 009	302 911
Log-likelihood	-1183.87	-890.39

*All values significant at p=0.05

For the binary logit model the point SVT estimate was 4.80 US$/hr with a 95% confidence interval between 4.47 and 6.47. In order to obtain the VRR we had to amend the figures presented by Iragüen and Ortúzar (2003) because the US dollar appreciated considerably with respect to the Chilean peso in the period between surveys (it went from Ch$ 500 to Ch$ 650, a 30% increase), whilst local prices only went up by 7.5%.

Thus, considering a dollar value of Ch$ 537.5, the VRR estimated from the logit model amounts to 290 009 US$/risk with a 95% confidence interval ranging from 241 171 to 349 699. For this model (column 2 of Table 6), both the SVAR and VRR decrease in relation to the interurban models, a result that seems once again eminently plausible (Figure 3). In fact, a focus group revealed that for most people, driving in urban environments is perceived to be safer than driving on interurban roads.

If we also take into account that most trips under consideration were made during peak-hours the results appear to be even more credible. As Gaudry and Lasarre (2000) assert, road congestion is probably one of the two main causes helping to reduce fatal accidents within advanced western nations and it is very likely that congestion induces people to have a higher feeling of security (Hauer, 1997). This phenomenon should apply for

people living in Santiago and, hence, it is reasonable to expect that these facts translate into a smaller VRR.

Lastly, column 3 of Table 6 displays results for the mixed logit model. Although, there is a clear improvement in fit, the subjective values remain very similar.

In section 3 we mentioned that this last survey had been answered by a higher proportion of females and young people. The former tend to have a higher WTP for safety and the latter a lower WTP for safety (see Rizzi and Ortúzar, 2003; Iragüen and Ortúzar, 2003). Comparatively though, there was a higher proportion of young people than females in the sample, so the reported figures could be somewhat downward biased in comparison to the first two surveys.

We did not attempt to pool the three data sets. From visual inspection, it is clear that the parameters in Table 6 are in a different, higher, scale than those corresponding to the previous surveys. Thus, the interurban models are subject to greater variance than the urban model.

4.3 Deriving a general relationship for the VRR

The estimated VRRs for each survey can be considered valid only within the neighbourhood of the risk measure for each particular road. However, it is apparent from the outcome of each survey (see Figure 1) that there exists a global relationship between the level of risk and the VRR and we will now proceed to estimate it. First of all, we have to decide what values should we consider for this task. Mixed logit models are superior for predicting market shares and for computing individual WTP values (Train, 2003; Sillano and Ortúzar, 2003); however, our main concern is with mean sample WTP values (i.e. the figure to use in a potential cost-benefit analysis) and with regard to such estimates logit models are known to perform well. In addition, logit models and their confidence intervals provide us with a range of values that include all mean sample values estimated with the mixed logit models. Hence, we decided to base our analysis on the binary logit model results. For the interurban case, we will consider results from Table 4 and for the urban case results from Table 6.

Based on our observations about three different levels of fatal risks and their respective VRRs, we approximated this relationship by two straight lines. Unfortunately, there are not enough degrees of freedom to test the validity of the fit, but at least it suggests how the VRR may vary according with different levels of risks associated to different road environments. The following two lines establish the sought after relationship (Figure 4):

$$VRR = \begin{cases} 3.07 \cdot 10^{16} \cdot (risk\ level) - 9.52 \cdot 10^{15} & if\ risk \geq 5.09 \cdot 10^{-6} \\ 9.91 \cdot 10^{10} \cdot (risk\ level) + 1.07 \cdot 10^{5} & if\ risk < 5.09 \cdot 10^{-6} \end{cases} \quad (7)$$

These reveal that the WTP curve for safety is indeed of the form shown in Figure 1; as the initial risk level decreases, willingness to pay also decreases but at a decreasing rate. It is reassuring to observe that in spite of our limited data we were able to establish empirically the correct expected theoretical pattern. Equation (7) can only be considered indicative within the range of the data and we do not suggest to apply it outside its range. Table 7, column 2 gives an approximate idea of the values implied by (7).

Columns 3 and 4 display the inferior and superior limits of the 95% confidence intervals[7]. As can be seen, these intervals tend to narrow as the risk of death diminishes.
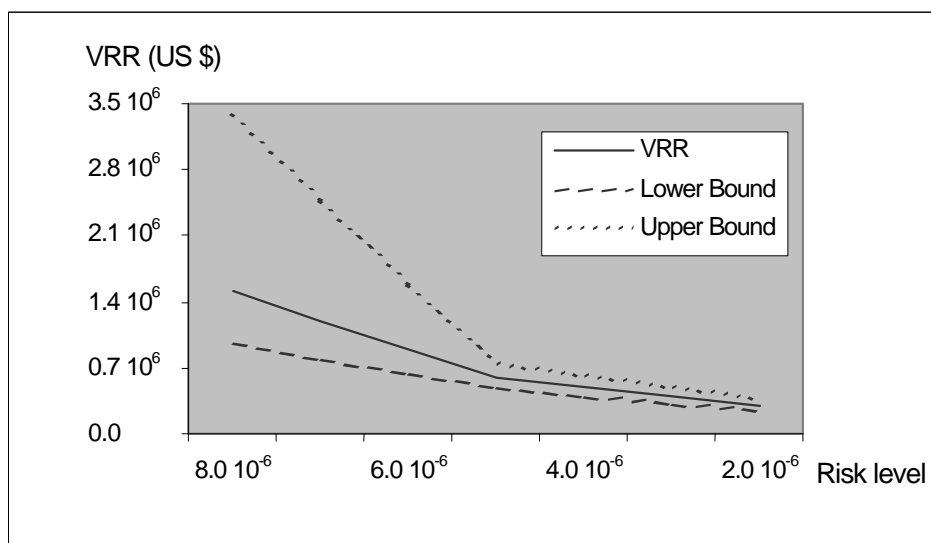

Figure 4: The VRR and its 95% confidence interval

Table 7. Implied VRR as a function of initial risk

Level of risk	VRR(US$*10^3/risk)	95% Confidence interval (US$*10^3/risk)	
8·10^{-6}	1505	962	3402
7·10^{-6}	1197	789	2491
6·10^{-6}	890	638	1581
5·10^{-6}	602	508	742
4·10^{-6}	503	400	617
3·10^{-6}	403	314	492
2·10^{-6}	304	249	368

Although our estimates are of a preliminary nature in terms of policy analysis, we believe that this approach is superior to one based in a unique VRR irrespective of the initial risk level and should lead to better resource allocation for safety improvements. For instance, some actions could be too costly for the safest roads, but may be justified for dangerous roads, thus preventing safety over-investment in certain routes at the expense of under-investment in less safer routes.

As an application of (7), imagine major safety public works on Route 5 in order to improve safety up to the level of Route 68; that is, a reduction of risk of 2.9·10^{-6} or 17 fatal victims (i.e. a 63% reduction in fatalities). According to (7), the toll could be increased by Ch$ 1556 (ie around US$ 3). The toll for the Santiago – Rancagua trip in 2000 amounted to Ch$ 3100, so the above figure would imply an increment of roughly 50%, which appears sensible.

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[7] The equation for the upper and lower bounds can be obtained upon request. The upper bound is represented by two straight lines in a similar fashion to the VRR curve; the lower bound curve is given by a second order polynomial.

5. Discussion

We have shown that the value of road safety may differ between different routes. This should prevent the use of a unique value of risk reduction (VRR) for different road contexts. Although this fact complicates matters, a simple way to overcome this difficulty is to try and establish a relationship between the risk level of a route and the VRR. This relationship should comply with economic theory in the sense that the higher the initial risk level and/or the higher the risk reduction offered, the higher the VRR should be.

Based on three different stated choice (SC) data sets we were able to establish the required relation. The VRRs obtained gave us an opportunity to perform an external validity test of the SC method. As we observed the expected theoretical relationship between risk level and VRR, we concluded that the external validity test yielded a positive result[8]. From this we reaffirmed our belief that SC is a powerful technique for estimating the VRR.

To improve on usual practice, we presented the risk information to respondents as numbers of fatal accidents and not as probabilities. This variable was correctly interpreted by them and when we translated results in terms of probabilities we found the correct economic outcome. On this issue we conclude that fatal accidents are a good risk proxy that can be easily interpreted by most people who *have* driving experience on the actual roads defining the SC surveys[9].

As caveats to our results three facts should be borne in mind. First, we are still developing the technique of SC applied to road safety and some improvements are being considered in ongoing research. Second, our samples are not strictly of a random nature, so our values may not be truly representative of population values. For example, we believe that all the figures presented may be upward biased since the average income of our samples is higher than that of the total population of road users. However, with proper adjustment these values could be used in Chile and could certainly be transferred to other Latin American countries (and even other second world countries) with more confidence than values transferred from the developed world.

The third point to consider is the definition of risk itself. There are many definitions of risk and it is difficult to decide which one is superior (see Shalom-Hakkert *et al*, 2002, for an interesting discussion). We consider risk as the probability of a car trip ending with a fatality: thus, to derive the VRR we need the number of fatal victims per accident and this value is highly variable. We decided against considering just the number of fatalities, since this number is even more variable than the number of accidents with fatalities (Fridstrom, 1999, chapter 6), but it may be considered in future work.

When comparing the VRR obtained within Chilean road contexts with international values, it is not easy to draw a definite conclusion. We have observed that the VRR tends to be related to the risk level, so differences can be important. We can only say

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[8] Even the values within the 95% confidence interval for each sample comply with the expected theoretical pattern.

[9] As a caution, we do not recommend to interview people who can not recall how dangerous the specific road is; in that case the number of accidents would be a figure devoid of any contextual meaning.

that for the safest Chilean roads - Route 68 and the urban case - our values tend to be much lower than those found for (even safer) roads in the developed word. For instance, our VRR estimates (considering confidence intervals) are lower than a set of values provided by Evans (1994) for the UK (1 million to over 3 million US$). On the other hand, VRR estimates for the more dangerous Route 5 span an interval even wider than that in the UK. As another yardstick, de Blaeij *et al* (2002) obtained a point estimate slightly superior to US$ 2 million for Dutch interurban roads (among the safest in the world) using SC; once again a value which is superior to all our point estimates.

Consider now the meta-analysis by Miller (2000) from which one could supposedly obtain the VRR for any country by transferring values based on a 1995 GDP/capita adjustment. He derived values for the Chilean case ranging from US$ 600 000 to US$ 900 000. These figures could be roughly compared to those for the VRR in Route 68 [518 796; 752 821], but in our opinion this is just sheer luck, as the per capita income of our sample is much higher than the Chilean 1995 GDP/capita required by Miller. We should also note that Miller's values are not sensitive to initial risk levels, so we do not know whether or not it is appropriate to apply his transfer function to different road environments. In particular we suspect it should not be applied to a route as unsafe as Route 5.

Taking all these facts into account, we observe that Chilean VRRs appear to be comparatively lower than VRRs estimated in industrialised countries (even after adjusting by income). To account for this difference we can suggest two reasons. First, we believe there are differences related to idiosyncratic risk perceptions. Unfortunately, road risk consciousness is not as high in Chile as in first world countries and many tend to believe that accidents simply occur and can not be prevented. Hence, there is a lower WTP for risk-reducing road safety measures. This finding will never show up if a meta-analysis does not include VRRs from developing countries and/or variables related to risk perception.

Second, the high VRR obtained in developed countries may be partly due to biases introduced by the extensive use of the contingent valuation (CV) technique. CV usually implies a trade off between probabilities of risk and money in a context not completely specified. Thus, it is not rare at all that high VRR could be obtained. The context in which we set up the choice situations here is well defined, easily understood by most people and real market restrictions are introduced to prevent respondents producing unlikely responses. This has the effect of tempering responses, and precluding people to produce "outliers". De Blaeij *et al* (2002) reported a similar finding[10].

To wrap up, we conclude that (a) SC is a promising questionnaire technique in order to elicit VRR; (b) accidents are better understood than probabilities of risk; (c) the VRR for road contexts should include a range of likely values depending of the risk level of each route and (d) our findings provide a set of figures for road safety planners in Latin American and other developing countries, which are superior (more credible) to a simple transfer from industrialized nations.

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[10] They state among other reasons for this phenomenon (a) the public good nature of the risk under analysis and (b) the definition of the payment mechanisms. However, they do not attempt to give any explanation on whether or not the survey instrument could affect the outcome of the experiment.

Acknowledgments

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