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Valuation of safety under reference-dependent evaluation of income

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ABSTRACT

We analyze data of a Spanish nationally-representative survey where subjects reported their willingness to pay (WTP) for road safety improvements, specifically they hypothetically paid for a reduction of the risk of a road fatality and several injuries. Respondents also reported their current income (CI) and permanent income (PI). The latter refers to their normal income once they considered various stages of low/high earnings throughout their entire lives. Consequently, we define relative income as the comparison of CI with respect to PI. Three income frames are generated as explanatory variables: gain (with CI > PI); neutral (with CI = PI); and loss scenario (with CI < PI). Surprisingly, we find that conditional on current income, and on a set of characteristics, those respondents in gain frame reported higher WTP than those in neutral and loss scenario. Further analysis shows that the income frames effect is higher and more significant for the older half-sample (>45), being about three or four times higher than for the younger subset. Possible interpretations of the role of PI as a reference point are considered given the results. A reference-dependent utility function of income, where PI is the reference point, is proposed to describe the monetary valuation of safety within the theoretical framework previously developed in the safety economics literature.

1. Introduction

Monetary valuation of safety improvements is crucial for the appraisal of (road) safety programs. Also, it is widely accepted that willingness to pay (WTP) for reduction of death and injury risks should be the grounds for the estimation of value of statistical life (VSL) and value of preventing an injury (VPI) (Andersson, 2007, 2013; de Blaeij et al., 2003). In this sense, one important aspect is the relationship between WTP and income because it justifies adjustment of economic values to new income situations between social groups and updating over time. For example, the UK Department for Transport updates the VSL and VPI indexed by GDP per head (see Spackman et al., 2011). In previous studies it has been estimated a significant positive relationship between income and WTP for safety improvements (Andersson, 2007, 2013; Hammitt and Robinson, 2011; Lindhjem et al., 2011; Persson et al., 2001a; Jones-Lee et al., 1985, 1993), implying that safety is a normal good.

The link between income and WTP has been predicted by theory in safety economics. Specifically it has been stated that the marginal rate of substitution (MRS) of wealth for risk of death (or injury) for an expected utility maximizer increases with wealth (Jones-Lee, 1974, 1976, 1989). Indeed this theoretical prediction is more general than what has been empirically found. Wealth is a broad concept that includes not only income but accumulated assets. Even more, income can be divided into current, past and future income. In this sense current, past and future income should affect WTP in the same manner because they are different components of wealth. However, previous studies only take into account current income (Andersson, 2007, 2013; Hammitt and Robinson, 2011; Lindhjem et al., 2011; Persson et al., 2001a; Jones-Lee et al., 1985, 1993). So far different incomes throughout the economic life cycle have been ignored. Despite the fact that current income should be closely correlated with past and future income we can establish different situations in which they do not coincide. Consider the average or "normal level" of income throughout the entire life of an individual, also called permanent income. There are situations in which individuals are in a low or high income stage according to whether they are below or above their permanent income. Previous theoretical and empirical analyses of safety valuation do not differentiate between these situations. However an interesting question is whether people's WTP is affected by the stage of the economic life-cycle and what is the role of the permanent income (PI) in addition to current income (CI).

There is a growing literature indicating that the behavioral effect of PI (i.e. the average of past, current and future income) on people is different to the effect of CI as explained by Clark et al. (2008). They postulate that past and future income is a reference point (or reference income) in comparison to which a person

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evaluates current income. In this sense, utility is positively related to relative income, defined as the comparison of current income with respect to income in the past and future. As a consequence, utility increases with current income but decreases with past and (expected) future earnings. There is evidence from the subjective well-being literature supporting this idea. For example, it has been found that past income negatively affects job satisfaction (Clark, 1999; Grund and Sliwka, 2007). Also in McBride's Experiment (2010) subjects played matching pennies games against a computer such that the aspiration levels of earnings were manipulated and a negative correlation between this expectation and satisfaction at the end of the game was found.

Even more, the evaluation of money with respect to a reference point is already present in one of the most prominent model of decision under risk, prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). It entails that risk preferences shift when lottery outcomes are framed as losses rather than as gains. People are in general risk averse in the gain domain and risk seekers in a loss scenario. Also individuals are specially risk averse when alternatives are mixed lotteries (i.e. lotteries with positive and negative outcomes). They account for these behavioral patterns by considering a value function with a varying shape for losses and gains. Specifically the value function of money has the properties of loss aversion and diminishing sensitivity to outcomes. Accordingly, we can consider that a person with current income above (below) past and future income is in a gain (loss) scenario. Therefore the shape of the utility function of income would vary in those two situations as suggested by prospect theory.[1]

In the present paper, we show that if a reference-dependent utility function is consider into a model of safety valuation previously used in the literature (see for example Carthy et al., 1999; or Jones-Lee, 1976) it is obtained that, given a constant level of CI, those people who are in a gain frame (henceforth G), with CI > PI, are willing to pay more for safety improvements than those in a neutral (henceforth N), with CI = PI, or loss income frame (henceforth L), with CI < PI. This reference-dependent utility function depends on both CI and PI, but the role of the latter is that of a reference point. Also, it has the typical properties of loss aversion and diminishing sensitivity (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992).

In addition we analyze data from a contingent valuation (CV) study in Spain carried out to elicit the VSL and the VPI in the context of road safety. In the survey respondents were asked about their WTP for reducing the risk of death and several non-fatal injuries. They also reported their monthly current income and their monthly permanent income. We estimate a quantile regression with WTP as dependent variable, and income frames dummies, CI and socio-demographic characteristics as explanatory variables. In the first place, we find the same positive effect on WTP for CI as in previous studies. However, we find that WTP is higher for those subjects included in G than for those in N and L. Given that this effect is found after controlling for CI we have a negative relationship between wealth (generated in the past or future) and WTP. This result is opposite to previous theoretical predictions (Jones-Lee, 1974, 1976, 1989) but consistent with the above mentioned reference dependent utility function. We also find that the effect of the income frames is higher and more statistically significant for the older group (those above 45) being about three or four times higher than for the younger subset. To the best of our knowledge the theoretical and empirical findings in this study are innovative and have never been exploited in the safety literature.

In the next section we present a reference-dependent utility function within the theoretical framework of valuation of safety. Then details about the CV study are exposed. Results are reported in Section 4. Eventually Section 5 contains a discussion and conclusion.

2. A reference dependent utility function

In this section we follow the theoretical framework developed in Carthy et al. (1999) and Jones-Lee (1974, 1976). It can be shown that under expected utility theory the theoretical MRSs of wealth for risk of death and injury, respectively, are given by the next expressions:

$$m_{\mathrm{D}} = \frac{\partial w}{\partial p} = \frac{U(w) - D(w)}{(1-p)U'(w) + pD'(w)}. \tag{1}$$

$$m_{\mathrm{I}} = \frac{\partial w}{\partial q} = \frac{U(w) - I(w)}{(1-q)U'(w) + qI'(w)}. \tag{2}$$

Where the numerator is the difference between the utility of wealth conditional on normal health, $U(w)$, and the utility conditional on death, $D(w)$ (at Expression (1)), or the utility conditional on suffering an injury, $I(w)$ (Expression (2)). The denominator is a weighted average of the marginal utilities. The probability of having a fatal and non-fatal accident are p and q respectively.

Expressions (1) and (2) are very helpful because they allow us to study the relationship between the MRSs and wealth. It can be shown that m_{D} (and m_{I}) increases with wealth as analyzed in Jones-Lee (1974, 1976). Sufficient assumptions can be considered for this result to be true: (a) utility of wealth is increasing and marginal utility is decreasing with wealth, so $U'(w) > 0$, $U''(w) < 0$, $D'(w) > 0$, $D''(w) < 0$, and $I'(w) > 0$, $I''(w) < 0$; (b) also, utility and marginal utility of wealth is higher conditional on good health than conditional on death or injury, so $U(w) > D(w)$, $I(w)$ and $U'(w) > D'(w)$, $I'(w)$.

Now the main modification we introduce into this model is the consideration of a different effect of current income and permanent income on the utility function. Consider that the utility conditional on normal health, $U(ci,r)$, depends on current income, ci, and on a reference point, r. Where r is given by the permanent income. Utilities conditional on death and on injury depend only on current income: $D(ci)$ and $I(ci)$ respectively.[2] In this setting, subjects are willing to trade current income for safety improvements. Therefore we can compute the theoretical MRS of ci for risk of death or injury (see Appendix A):

$$m_{\mathrm{D}}(ci,r) = \frac{\partial ci}{\partial p} = \frac{U(ci,r) - D(ci)}{(1-p)U_{ci}(ci,r) + pD'(ci)}. \tag{3}$$

$$m_{\mathrm{I}}(ci,r) = \frac{\partial ci}{\partial q} = \frac{U(ci,r) - I(ci)}{(1-q)U_{ci}(ci,r) + qI'(ci)}. \tag{4}$$

Here m_{D} and m_{I} are defined as a function of current income, ci, and the reference point, r. We have a representation of $U(ci,r)$ in Fig. 1. This function has the following properties:

[1] The concept of value function is normally used in the context of prospect theory (Kahneman and Tversky, 1979; and Tversky and Kahneman, 1992). In the present context we will use the more traditional concept of utility function of income as in Safety Economics (see Carthy et al., 1999; or Jones-Lee, 1976). Both terms refer to the same idea of attaching a number to each amount of money in order to explain behavior.

[2] We assume that the utility conditional on death and injury are not reference dependent for ease of exposition. However, the same theoretical results shown in this section can be derived in case that we consider $D(.)$ and $I(.)$ to be affected by r. In that case we just have to assume that the marginal effect of r is higher conditional on normal health, i.e. $|U_r(ci,r)| > |D_r(ci,r)|$, $|I_r(ci,r)|$.