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# Joint models for noise annoyance and willingness to pay for road noise reduction

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## Abstract

Recent contingent valuation (CV) studies of the willingness to pay (WTP) for road noise reduction have used stated annoyance as an independent variable. We argue that this may be inappropriate due to potential endogeneity bias. Instead, an alternative model is proposed that treats both WTP and annoyance as endogenous variables in a simultaneous equation model as a combination of a linear regression with an ordered probit with correlated error terms and possibly common parameters. Thus, information on stated annoyance is utilised to estimate WTP with increased efficiency. Application of the model to a dataset from Copenhagen indicates a potential for improving the precision of the estimate of WTP for noise reduction with CV data. © 2005 Elsevier Ltd. All rights reserved.

*Keywords:* Joint ordered discrete-continuous models; Valuation of noise reduction; Noise annoyance; Willingness to pay

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## 1. Introduction

In this paper we consider the statistical specification of models for the marginal willingness to pay (WTP) for noise reduction, obtained from valuation surveys. Traditionally, property value

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methods have been applied to measure the social cost of the annoyance from road noise, but an increasing number of studies now use contingent valuation (CV) to evaluate the WTP.<sup>1</sup> Different valuation scenarios have been used in these studies. A number of recent CV studies have adopted methods developed by noise researchers, who for several years have analysed the impact of noise on the experienced (self-reported) annoyance. This line of research has developed into standardised methods for asking questions in “socio-acoustic” surveys about level of annoyance using a five-point annoyance scale (ISO, 2003) and there now exists a large body of scientific evidence on the exposure–response relationship between noise and level of annoyance (measured as the probability of being annoyed at a particular annoyance level), e.g. Miedema and Oudshoorn (2001) and Klæboe (2003).

Examples of contingent valuation studies, which combine the socio-acoustic survey tradition with CV questions on the WTP for removing the noise annoyance include Navrud (2000), Lambert et al. (2001) and Bjørner (2004), and the approach is advocated by Navrud (2002) in his recent survey of the state-of-the-art of economic valuation of noise. The underlying idea is that estimates of the WTP conditional on annoyance levels can be combined with noise exposure–annoyance relationship to calculate the expected WTP for the relevant reductions in noise exposure. This involves, as a first step, estimation of annoyance as a function of noise and then, in a second step, estimation of WTP as a function of the stated annoyance level.

However, this sequential method opens the possibility of endogeneity bias, since unobservables in the model for annoyance and the model for WTP may be correlated. Thus, holding all observables constant an individual who for some unobserved reason states a higher annoyance level is also more likely to state a higher WTP. This introduces a correlation between the error term and the independent variables in the WTP equation, which renders the estimation of WTP inconsistent.

One solution to the endogeneity problem is to estimate a (one step) reduced form model, where WTP is estimated directly as a function of noise, i.e. without estimating the relationship between noise and annoyance. The data we apply were obtained from a combined socio-acoustic and contingent valuation survey from Copenhagen. Data on noise exposure of the respondents were also collected. In the survey an open-ended question format was used to elicit the WTP for avoiding noise annoyance. This yields a variable for WTP censored at zero. We estimate a reduced form model specified as a hurdle model (Wooldridge, 2002), which takes account of the censoring of the WTP in a more general way than the standard Tobit model.

The hurdle model provides unbiased estimates of the WTP, but it does not utilise the information revealed by the respondents when stating their annoyance levels. The information on annoyance is an important indicator of preferences for noise reduction and it therefore seems worthwhile to explore whether the information on annoyance may be used to improve the efficiency of estimates of the WTP for noise reduction. We consider two variations of a model where annoyance is considered an endogenous variable and estimated jointly with WTP. Given the ordinal nature of the annoyance variable an ordered probit is used to model annoyance, while a linear model is used to estimate  $\log(\text{WTP})$  (conditional on a positive WTP being observed). In the first version of the model the ordered probit and the WTP models are linked only through correlation

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<sup>1</sup> For a discussion of the pros and cons of the hedonic and contingent valuation methods with respect to noise see e.g. Navrud (2002) or Bjørner et al. (2003).

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