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Testing the slope model of scheduling preferences on stated preference data

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ABSTRACT

The valuation of travel time variability is derived either from a structural model, given information on departure time, or directly from a reduced-form model where departure time is assumed to be optimally chosen. The two models are theoretically equivalent under certain assumptions, hence are expected to yield similar results. We use stated preference data to compare the valuation of travel time variability under a structural model where trip-timing preferences are defined in terms of time-dependent utility rates, the "slope model", against its reduced-form model. Two choice experiments are used that are identical except one has a fixed departure time while the other allows respondents to choose departure time freely. The empirical results in this paper do not support the theoretical equivalence of the two models as the implied value of travel time variability under the reduced-form model is an order of magnitude larger. This finding, which is robust to various specification tests, is in line with a recent Swedish study by Börjesson, Eliasson and Franklin [*Transportation Research Part B: Methodological, **46**(7), 855–873 (2012)*]. Since our data allows a direct comparison of the two approaches, we are able to rule out some potential explanations lined up by past research for the observed discrepancy between the two models.

1. Introduction

Travel time variability, TTV for short, is an important consideration in trip scheduling, travel mode and route choice decisions. Although transport policy is often aimed at reducing average travel times, the variation in travel times has received increasing attention recently as increased variation represents a cost for travellers due to increased uncertainty and potential unexpected delays. Due to this, efforts are being made to reduce the degree of TTV by adding new road capacity and through the use of transport policy such as road pricing. A challenge in decision-making, regarding the choice of options to alleviate the uncertainty of travel times, is how to evaluate and compare benefits from alternative measures for reducing the variability of travel times.

Modelling travellers' behaviour in response to TTV is an integral part of travel demand analysis (Small and Verhoef, 2007; Carrion and Levinson, 2012). Broadly speaking, two main approaches have been developed in the literature: The scheduling approach (e.g Vickrey, 1969, 1973; Small, 1982; Noland and Small, 1995) and the direct approach or the mean-variance approach. In the scheduling approach, travellers are assumed to have a utility function that depends on their departure

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time and their preferences for being at the origin and destination, and it is usually assumed that they respond to TTV by maximising their expected utility given the travel time distribution. In the direct approach, on the other hand, it is assumed that travellers derive (dis-)utility directly from TTV. Following earlier work by Bates et al. (2001), Fosgerau and Karlström (2010) and Fosgerau and Engelson (2011) showed that the direct approach is, under some conditions, a reduced-form of the scheduling model, expressing the optimal expected utility as a function of the travel time distribution under the assumption that travellers choose their departure time optimally.

The two approaches are theoretically equivalent if: (a) travellers choose departure time to maximise expected scheduling utility knowing the distribution of travel times, (b) the distribution of travel times is independent of departure time, and (c) there is no dis-utility from uncertainty per se (Fosgerau and Karlström, 2010; Fosgerau and Engelson, 2011).[1] Hence, they can be expected to yield similar valuations of TTV, which is inferred from trip-timing preferences in the scheduling model and is directly related to a measure of the dispersion of the travel time distribution in the reduced-form model.

Despite the theoretical equivalence, empirical research reveals that the approaches could provide considerably different results (see, e.g. Hollander, 2006; Börjesson et al., 2012; Beaud et al., 2012). The discrepancy can be due to: (a) violation of assumptions implying the theoretical equivalence, (b) failure of the structural model (i.e., the scheduling model) to adequately capture important scheduling considerations in real life, (c) differences in the source or feature of data on which the models are applied, and (d) data that does not correspond to actual behaviour.

When estimating the value of TTV, one can choose to apply either approach provided the theoretical equivalence also holds empirically. If, however, results differ between the approaches, estimated values of TTV will depend on the chosen approach. To provide guidance in the choice of modelling approach, it is therefore imperative to empirically examine whether the valuation of TTV is transferable between the two approaches. Since there is no agreement on a preferred method for measuring scheduling preferences and presenting TTV in stated choice experiments, it is important to understand why the approaches could yield different results and possibly pinpoint the source of discrepancy as well as address some limitations in stated choice experiments that have critical impact on the estimates.

In this paper, we compare the two approaches using stated preference (SP) data from a survey designed to estimate the value of TTV. The analysis is based on the form of scheduling model developed by Vickrey (1973) and later analysed by Tseng and Verhoef (2008) and Fosgerau and Engelson (2011).[2] This model, known as the "slope model", considers journey scheduling choices in the presence of travel time variability, in the case where departure time is chosen in a continuous fashion. It assumes that travellers derive utility at a time-varying rate from time spent at the origin and at the destination, and that it is less and less attractive to spend time at the origin and/or more and more attractive to spend time at the destination such that at one point in time, t_0, it becomes more desirable to be at the destination than at the origin. It further assumes that utility rates are simple linear functions of the time of day. The slope model of scheduling preferences has the neat property that the theoretical cost of TTV is proportional to the variance of travel times.

We use SP data from two different choice experiments. Both experiments use the same sample of respondents drawn from a population of Danish car drivers commuting to work in the morning. Moreover, each choice experiment consists of six binary choices between travel alternatives characterised by a set of attributes. The attributes include a travel time distribution with two possible outcomes and their probabilities of occurrence. In one choice experiment, the only attributes are journey cost and the travel time distribution, while the other choice experiment in addition includes a departure time attribute. We use data from the first choice experiment to estimate the parameters of the reduced-form model and data from the second choice experiment to estimate preference parameters in the scheduling model.

The empirical results in this paper, which are robust to various sensitivity checks, do not support the theoretical equivalence between the scheduling and reduced-form models. The two methods are shown to yield very different results in terms of the value of TTV. Our analysis is closely related to a recent paper by Börjesson et al. (2012); however, it differs with regard to data. By using data that allows direct comparison between the two approaches, we can rule out some of the potential explanations for the observed difference between the two methods in their analysis. Because they estimated the scheduling model based on data without TTV, they could not rule out whether this has contributed to the observed discrepancy between the two models. The two SP games we designed to estimate the two models are much more similar to each other than the corresponding designs in Börjesson et al. (2012): Both our SP games involve TTV and use the same presentation for the distribution of travel times. The only difference between the games is that one includes a departure time attribute, while the other allows respondents to choose their preferred departure time. Compared to Börjesson et al. (2012), the similarity between the two SP games narrows down the list of potential factors differentiating the two models.

A further contribution of this paper is that it examines whether the results in Börjesson et al. (2012) who sampled users of scheduled services, namely train and metro, also holds for car commuters, alternative specifications of the marginal utilities of time, and for an alternative model specification with non-linear probability weighting (a rank-dependent utility

[1] While the equivalence of the two approaches was established earlier by Noland and Small (1995) and Bates et al. (2001) in special cases where travel times are assumed to follow particular distributions, Fosgerau and Karlström (2010) and Fosgerau and Engelson (2011) later showed that the equivalence holds irrespective of the form of the travel time distribution as long as its standardised distribution is independent of departure times.

[2] There is also another version of the scheduling model with constant marginal utility of time at the origin and piece-wise linear marginal utility of time at the destination (Vickrey, 1969; Small, 1982; Fosgerau and Karlström, 2010).