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On the identification of thresholds in travel choice modelling

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ABSTRACT

In this paper we demonstrate different approaches for estimating thresholds with respect to attribute differences in discrete choice models. The proposed new transformation functions can easily be applied in estimation software. The usefulness of these functions is tested with synthetic data. Extensive simulation shows that many observations are necessary to detect thresholds. And furthermore, the value of travel time savings of a model ignoring these thresholds is biased. The application to stated choice data reveals a significant threshold. However, the cause and the precise form of this threshold cannot be inferred from the data. The presented approach might also be useful to model thresholds in other contexts of choice behaviour.

1. Introduction

In this paper, we focus on empirical issues in estimating thresholds with respect to travel time differences by discrete choice models and the consequences of ignoring them in model estimation. New functions will be presented that permit the modelling of smooth thresholds. These functions can easily be applied in any estimation tool for discrete choice analysis that can handle non-linear utility functions. We demonstrate the usefulness of these functions with synthetic data and apply them to stated choice data. Based on the estimations, value of travel time savings are computed and compared between different model specifications. As we show, the estimated value of travel time savings can differ substantially from that of a model ignoring these thresholds. In this contribution a constant value of travel time savings, irrespective of the size of the time difference, will be derived. The discussion whether travel time savings should increase with the size of the time savings is beyond the scope of this paper. Besides the consequences for the value of travel time savings, the consideration of thresholds may be important for predicting choice behaviour.

The explicit consideration of thresholds with respect to travel time differences is a rather underrepresented topic in the literature on travel choice modelling. Essentially, such approaches focus either on utility or attributes. The former, which is based on indifference (utility) thresholds, has been modelled, for example, by Krishnan (1977), Lioukas (1984), and Cantillo et al. (2010). We, however, will concentrate on attribute thresholds. Work in this area has been done, for example, by Cantillo et al. (2006) and Li and Hultkrantz (2004). Empirical results support the existence of utility as well as attribute thresholds. The reasons for the existence of such thresholds can be various. For instance, people may not perceive small differences or even ignore them because they cannot make effective use of them. Furthermore, the cognitive decision costs of evaluating the alternatives might exceed the possible benefit that could be gained (Hultkrantz and Mortazavi, 2001, p.

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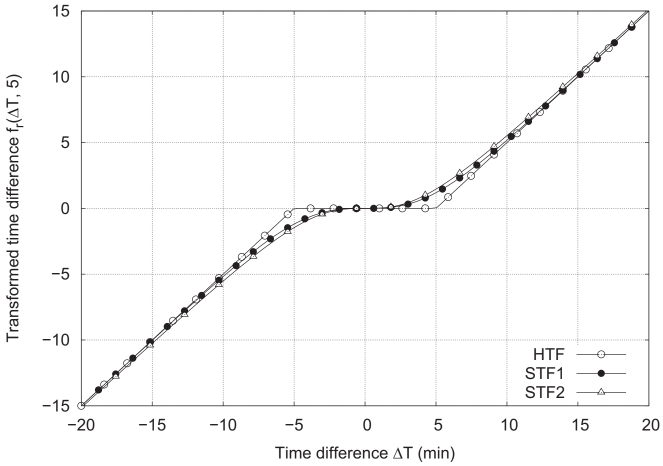

Fig. 1. Generic form of the transformation functions (2)–(4); for illustration purposes these functions are plotted for a threshold parameter $\alpha_r = 5$ min.

290). For the following analysis, however, it is not essential to detect the cause of the threshold but to consider it in the estimation process.

The structure of the paper is as follows. In Sections 2 and 3, the modelling approach and the calculation of the value of travel time savings are described. Under the use of synthetic data the approach is tested in Section 4. In Section 5, the modelling approach is applied to stated choice data. Finally, Section 6 concludes with a discussion.

2. Modelling approach

We model the choice between two alternatives of the same category that are characterised by the same attributes, i.e., unlabelled alternatives (e.g. route choice between a cheap but slow and a fast but expensive train connection). The modelling approach focuses on detection of possible deviations in the sensitivity to attribute differences between both alternatives, if these differences are small. The aim is to test whether travellers exhibit different sensitivities between large and small travel time differences.

It is assumed that trip makers always choose the option with the highest utility, which is decomposed into a deterministic (V) and a stochastic (ε) part. The stochastic component is assumed to be iid Gumbel, and, therefore, the difference between the two stochastic components is logistically distributed. In the following, we consider just the utility difference between the two alternatives, because this is what matters for the choice decision. The utility difference is a function of the attribute differences. To model potentially different sensitivities depending on the size of time differences, an attribute transformation function is applied. The parameter α_r of the transformation function has to be estimated along with the remaining coefficients of the model.

We assume that the utility difference ΔU is separable in time differences between alternatives ΔT (in minutes) and cost differences ΔC (in Swiss francs) according to

$$\Delta U(\Delta T, \Delta C) = \Delta V(\Delta T, \Delta C) + \Delta\varepsilon = \beta_T\, f_\mathrm{r}(\Delta T, \alpha_\mathrm{r}) + \beta_C \Delta C + \Delta\varepsilon \tag{1}$$

and that the time component is non-linear according to the following three specifications of the transformation function $f_r(\Delta T, \alpha_r)$ (cf. Fig. 1).[1]

$$f_\mathrm{HTF}(\Delta T, \alpha_\mathrm{HTF}) = \begin{cases} 0 & \mathrm{abs}(\Delta T) < \alpha_\mathrm{HTF} \\ \mathrm{sign}(\Delta T)(\mathrm{abs}(\Delta T) - \alpha_\mathrm{HTF}) & \mathrm{abs}(\Delta T) \geq \alpha_\mathrm{HTF} \end{cases} \tag{2}$$

$$f_\mathrm{STF1}(\Delta T, \alpha_\mathrm{STF1}) = \Delta T - \alpha_\mathrm{STF1}\tanh\left(\frac{\Delta T}{\alpha_\mathrm{STF1}}\right) \tag{3}$$

$$f_\mathrm{STF2}(\Delta T, \alpha_\mathrm{STF2}) = \Delta T\left(1 - 1\Big/\sqrt{\left(\frac{\Delta T}{\alpha_\mathrm{STF2}}\right)^2 + 1}\right) \tag{4}$$

Eq. (2) is a hard threshold function (HTF), which is usually applied to model thresholds. It is a piecewise linear function, where the slope within the threshold area is zero. For functions (3) and (4), called soft threshold functions (STF), the slope continuously increases from zero to the limit of one. Fig. 1 depicts the three different transformation functions for a threshold of 5 min.

[1] For procedures to estimate such models see, for example, Train (2009).