Value-of-time through a financial crisis: temporal and inter-temporal variation

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Abstract

Traditionally, the forecasting of the value-of-time assumes proportionality to income. This way of forecasting the value-of-time considers only the "cost-side" and assumes that travel time preferences are unchanged. However, there are numerous reasons why time preferences could change over times among which, autonomy, increased comfort and flexible communication via mobile broadband solutions, could be examples. In this paper we look into the dynamics of the value-of-time by estimating the value-of-time in a pooled cross-section model. Data originates from a large-scale Danish travel survey from 2006 to 2017 with more than 150.000 individuals and almost 500.000 trips. The period is interesting from a research perspective as it offers substantial variation in income and travel cost and at the same time represent a phasing-in period for mobile-broadband solutions from almost no coverage to full national coverage. We show that the inter-temporal increase in the value-of-time across the period agrees well with the increase in the disposal income and has elasticity close to unity, whereas the correlation to GDP is relative poor. Secondly, we show that the intra-temporal variation across income segments is stable across years and has an elasticity, which is approximately 0.5. Results are followed by an intensive Booth Strapping exercise from which, value-of-time variation across years and income groups are presented.

Keywords: value-of-time, forecasting, financial crisis, income effects, bootstrapping.

Introduction

The value-of-time measures the monetarized value of travel time savings and is an important part of most appraisal studies. Consumer benefits resulting from travel time savings, which could result from new infrastructure or pricing policies, typically dominates most other monetarised components in cost-benefit studies (Verhoef, 1994; Goodwin and Persson, 2001; Knudsen and Rich, 2013).

Contrarily to other model parameters, the value-of-time cannot be assumed constant over time. Time is a limited good and as productivity and income increases the relative value of time increases as well. Historically the projection of the value-of-time has been closely linked to the income growth, which for many practical applications is typically approximated by GDP growth. Due to a substantial amount of uncertainty in predicting the relationship between income and the value-of-time, it is common to apply relative simple "rule-of-thumps" estimates, which is measured as elasticity to income. A number of studies have argued for elasticities less than unity (Algers et al., 1996; Ramjerdi et al., 1997). Specifically, the HEATCO study (Heatco, 2006) which was based on a meta-analysis, found that the elasticity to income was 0.7 and this was proposed as a basis for project appraisal at the European level. Fosgerau (2005) found cross-sectional (after-tax) income elasticities not significantly different from 1.0 for non-work travellers. The unity elasticity assumption is also recommended by Webtag (2016) and is the ruling standard for appraisal in the UK. Previous findings from Sweden and Norway (Algers et al., 1996; Ramjerdi et al., 1997) suggested significantly lower values, whereas other studies find elasticities significantly above 1. One example of the latter is in Douglas and Wallis (2013) who find higher than unity elasticities for Australia and New Zeeland by looking at the period 1990-2012. However, as suggested by Mackie et al. (2003) it is not clear what the elasticity should be and they continue to argue that "*….all that we can reasonably conclude is that since time savings are not an inferior good the income elasticity is expected to be positive*". The challenge is that the inter-temporal value of time is influences by a whole range of factors, which either directly or indirectly may influenced the disutility of travel and the cost of travel. Still, from a simple forecasting perspective the choice of elasticity could make a significant difference in the valuation of different projects. Generally speaking, if the elasticity is high (and if the increasing income is assumed to increase over time), it will amplify travel-time differences and projects that perform well according to travel time savings will be preferred. If on the other hand, the elasticity is low, it will put less weight on travel time effects and more emphasis on other external cost factors, such as accidents, noise and emissions.

Model

In order to estimate the VoT over time we carry our repeated estimations based on a large ongoing national travel survey dataset from 2006 to 2017 for Denmark. We estimate VoT on the basis of repeated cross-section data in order to assess if preferences for time and cost changes during the period. As pointed out in Wooldridge (2002), every method that applies to pure cross section analysis can be applied to pooled cross sections although it is essential to include time-specific dummies combined with mode-choice dummies to filter out irrelevant variation over time.

Rather than estimating models for single years, the estimation is carried out for ten "year clusters" of three consecutive years. Each cluster is referred to as $y = 1, \dots, Y$ and utility functions now reflect utility for individual n in a given cluster y, e.g. $V_{n,1}(m), \dots, V_{n,y}(m), \dots, V_{n,Y}(m)$. Hence, the first cluster cover the period from 2006-2008, the next cluster the period from 2007-2009 whereas the last cluster cover the period from 2015-2017. This means that the estimated VoT for a given cluster represent an average over three years and that the VoT across clusters is essentially a moving average. The benefit of this is that we have more data available for the estimation of the different models and in particular for the estimating of the correlation between income and VoT. Another desirable effect is that the VoT, due to the underlying lag-effect, become smoothened over time.

As discussed in the introduction there is strong empirical evidence for positive correlation between income and VoT: The higher the income the higher the VoT. However, we need to distinct between two different effects in the following:

i) inter-temporal effects of increasing income over time.

ii) intra-temporal effects, which reflect VoT heterogeneity across a population.

Empirically these are typically different. A common approach when applying transport models is to reflect inter-temporal effects through a VoT-to-GDP elasticity. The range of this elasticity typically varies from 0.5 to unity. Intra-temporal elasticities on the other hand, reflect that in a given year, high-income groups will have a higher value-of-time compared to low-income groups. These elasticities are typically found to be significantly lower than unity.

To be able to reveal both Intra- and intertemporal effect we consider, for each cluster y, differences in VoT over different income groups by using an indicator approach. We estimate J separate cost-parameters $\beta_{c1}, \ldots, \beta_{cJ}$ for J different income groups for each cluster. Hence,

$$(1) \quad V_{n,y}(m) = k_{m,y} + \beta_{t,y} g\left(t_{n,m,y}\right) + \sum_{j=1}^{J} \left[\beta_{c,j,y} 1_n(j,y) f\left(c_{n,m,y}\right)\right] + \epsilon_{n,m,y}, \forall n, m \in D_n, y = 1, \ldots, Y$$

In equation (1) $1_n(j,y)$ represent an indicator function such that $1_n(j,y) = 1 \Leftrightarrow n$ belongs to income group j in cluster y whereas $1_n(j,y) = 0 \Leftrightarrow n$ does not belong to income group j for cluster y. We consider four Income groups which are defined according to empirical quartiles, hence, income group 1 represent the 25% individuals with the lowest annual personal income whereas group 4 represent the 25% individuals with the highest incomes. The benefit of the indicator approach is that we assume very little about the model structure but simply reveal preferences for the different groups.

Due to the clustering of years, error terms $\epsilon_{n,m,y}$ are correlated across y. This would require a robust covariance estimator if common parameters were estimated across y. However, in our case we consider each cluster as an entirely self-contained model which does not share parameters across clusters. It means that preferences across clusters, as represented by model parameters, will be consistent and efficient for each cluster.

The inter-temporal VoT variation can be investigated by comparing the average VoT between time periods and for different income groups. The average value-of-time for y, j and m is shown in (2) below.

$$(2) \quad VoT_{y,j,m} = \frac{1}{N_{y,j}} \sum_{n=1}^{N} 1_n(j,y) \frac{g'\left(t_{n,m,y}\right)}{f'\left(c_{j,n,m,y}\right)}, \forall\, y = 1, \ldots, Y, j = 1, \ldots, J$$

Where $N_{y,j}$ is the number of individuals for cluster y and income group j. In the following, based on the estimated parameters, we will only consider averages over m. It should be remembered that m, in this context, represents only those modes with associated monetary costs. In other words, walk and bike is not included.

For a given income group j we define the inter-temporal variation as;

(3) $$Q(j) = \left(VoT_{y=1,j}, VoT_{y=2,j}, \dots, VoT_{y=Y,j}\right), \forall\, j = 1, \dots, J$$

Which can be normalise with respect to $VoT_{y=1,j}$ in order to reveal relative growth during the period. The intra-temporal variation on the other hand, reflects the variation across individuals for a given cluster y and is given by;

(4) $$H(y) = \left(VoT_{y,j=1}, VoT_{y,j=2}, VoT_{y,j=3}, VoT_{y,j=4}\right)$$

Results

Below in Figure 1 we present the estimated inter-temporal growth in the value-of-time for income quartiles. It is notable that the financial crisis result in a temporarily dip in the value of time for 2007-2008 but also that the value-of-time exhibit a relative stagnating pattern in the years of the crisis with a relative modes growth. However, after the crisis we see stronger growth but also a temporally setback around 2015.

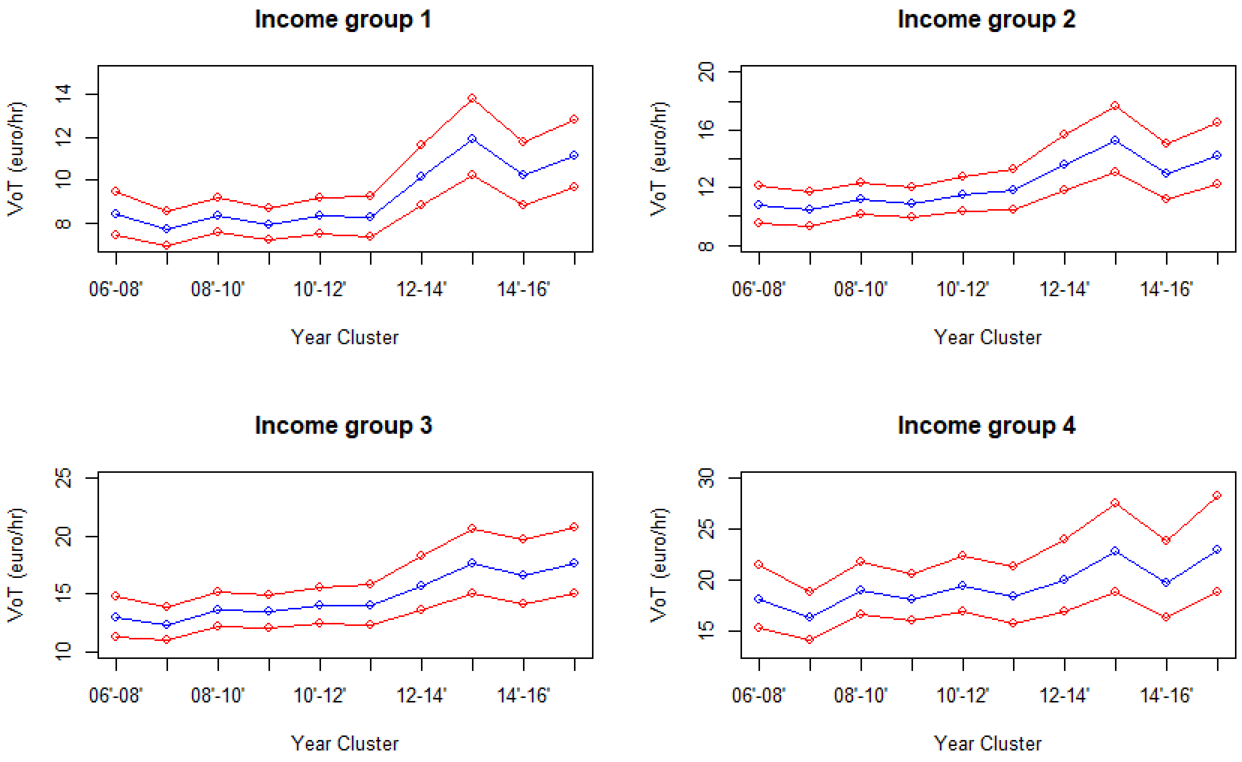

Figure 1: Development in the Value-of-time for four income quartiles for 10 year clusters.