

Estimating the Inter-Temporal Income Elasticity
of the Value of Travel Time Savings
- Evidence Based on Compensated Wage Differentials
using Swedish Revealed Preference Data

Jan-Erik Swärdh*

April 20, 2007

Work in progress - please do not quote. Comments are welcomed.

Abstract

The purpose of this paper is to estimate the inter-temporal income elasticity of the value of travel time savings (VTTS). This is performed on Swedish revealed preference data, where job changer's individual wage premium for commuting time changes is used as the proxy for the VTTS. The panel structure of the data imply the additional possibility to use lagged income variables on individual level to estimate the inter-temporal elasticity. From being accepted and practically used as unity, later empirical research suggest that the income elasticity is less than unity. However, by following the suggestion of Fosgerau (2005) to use the net income, the empirical results show no evidence of this elasticity being less than one in Sweden. In addition, this result is remarkably stable over a large number of different empirical specifications, including a Heckman selection estimation. Finally, this result can be viewed in the light of the recent recommendation of an EU financed project to harmonize cost benefit analysis input values in Europe (Heatco, 2006), which suggests an inter-temporal income elasticity of 0.7.

Keywords: Value of Travel Time Savings, VTTS, Inter-Temporal, Income Elasticity, Revealed Preferences, Sample Selection

JEL codes: C81, D91, R49

*VTI - the Swedish National Road and Transport Research Institute, Box 55685, S-102 15 Stockholm, Sweden, Visit: Lindstedtsvägen 24, KTH Campus Valhallavägen, Tel: +46 (0)8 555 770 28, E-mail: jan-erik.swardh@vti.se.

1 Introduction

The inter-temporal income elasticity of the value of travel time savings (VTTS) may have a substantial influence on cost benefit analyses (CBA) of investments in the transport infrastructure. The reason is both that the VTTS usually accounts for a large share of the benefits related to such investments¹ and that the life time of transport infrastructure usually is relatively long.

In early years, the assumption regarding the VTTS was that it is a function of the average wage rate implying that the income elasticity of VTTS is unity. The theory suggest, however, that the VTTS are indeed positively related to income but not necessarily in any specific direction. Furthermore, empirical studies suggest that the VTTS has increased over time but less than proportionally to income. In fact, the empirical findings suggest an elasticity of between 0.25 and 0.75. (Hensher and Goodwin, 2004)

Most of these studies are either performed on a single cross-sectional data set or by comparing several cross-sectional studies conducted at different times, e.g. by a meta-analysis. Still, the policy interest lies in the inter-temporal dimension if the question is whether the VTTS should be increased over time in a CBA. As far as I know, no study use individual panel data to estimate the income elasticity of the VTTS making the motivation of such a study straight-forward.

¹Hensher and Brewer (2001, p. 85) notes that more than 70 percent of total user benefits in many transport investments corresponds to the VTTS.

The purpose of this paper is to empirically estimate the inter-temporal income elasticity of the VTTS using Swedish revealed preference data. The data consist of a rich administrative micro level data set combined with actual travel times between small homogeneous geographical areas (SAMS²) in Sweden. One special feature is the use of implicitly revealed individual VTTS as the dependent variable in the analysis. This approach is inspired by the theory of compensated wage differentials³ where the VTTS is defined as the marginal rate of substitution between the wage and the commuting time.

The rest of the paper is organized as follows. The next section outlines how the VTTS and the corresponding income elasticity have been assessed during the recent decades. It also briefly discusses different views among researchers as well as the praxis concerning the income elasticity of the VTTS in CBA:s. In section 3, the methodology, including the model, the data, sample restrictions and sample selection problems, is presented. Section 4 presents the empirical results and a set of sensitivity analyses. Finally, the paper is concluded in section 5.

²SAMS is short for Small Area Market Statistics and Sweden consists of 9230 SAMS. Although the population is not equally distributed between the SAMS, the Swedish population of approximately 9 million citizens, makes each SAMS to consist of about 1000 citizens on average.

³Also known as equalizing differences. See Rosen (1986) for an overview of this theory.

2 Background

A well accepted opinion, supported by most relevant theoretical and empirical work, is that the VTTS is increasing in income, i.e. the income elasticity of the VTTS is positive⁴ (Hensher and Goodwin, 2004). From the simplest theoretical microeconomic model of time that predicts a VTTS equal to the wage rate (Becker, 1965), it immediately follows that the income elasticity of VTTS is unity. This also holds for a simple goods-leisure model (e.g. McFadden, 1974) as well as for models interpreting the VTTS as a fraction of the wage rate. Based on those results, a unit inter-temporal income elasticity of VTTS has been praxis in most countries up to now.

However, during the last decades, there is a number of empirical studies finding an income elasticity significantly lower than one. The British time valuation study in 1987 was the first to point out that although a positive relation between income and VTTS exists, this relation is decreasing when the income increases. Furthermore, Wardman (2001) suggests an income elasticity of 0.6 based on a meta-study of a large number of British cross-sectional studies. In addition, the rejection of a unit income elasticity is found also in other studies

⁴Most countries, e.g. Sweden, is not using differentiated VTTS with respect to income cross-sectionally. The reasons are probably that it may lead to non-desirable income distribution effects like higher transport infrastructure appraisals in high-income regions and that the transport agencies demand as homogeneous time values as possible. However, the adjustment of VTTS over time with respect to a mean expected income increase does not lead to differentiated VTTS with respect to income in a cross-sectional dimension.

(Wardman, 2004; Fosgerau, 2006). Gunn (2001) draws conclusions from several VTTS studies based on data of both revealed preferences and stated preferences from different countries. He concludes, inter alia, that the mean VTTS in the Netherlands has hardly changed between 1988 and 1997 despite a considerable mean income increase during this period. The interpretation consists of a decreasing disutility of travel time thanks to better possibilities of devoting the travel time to valuable activities, e.g. by using lap-tops and mobile phones. Axhausen et al. (2006) estimate the income elasticity for commuting travel time in Switzerland to be as low as 0.17. Still, their income variable is defined in intervals which might cause problems with the precision of the estimates. Finally, an EU-financed project, Heatco (2006)⁵, suggests that, when no country-specific results are obtainable, the VTTS should be adjusted over time with an income elasticity of 0.7 based on the result of a meta-study of Shires and De Jong (2006).

Fosgerau (2005), however, estimates the income elasticity to not being significantly lower than unity. Furthermore, he points out several reasons for the estimated income elasticity of the VTTS being significantly lower than unity in most recent applications. First, most studies are performed using gross income instead of net income. The net income is the relevant part for the traveler since

⁵Developing **H**armonized **E**uropean **A**pproaches for **T**ransport **C**osting and **P**roject **A**ssessment.

it can be used for consumption. In the case of a perfectly linear tax system the use of net income and gross income respectively yields the same estimate of the income elasticity. However, when the tax system is progressive, like in most western European countries including Sweden, the income elasticity is higher when net income is used instead of gross income (Fosgerau, 2005). Another point is that the total travel time presumably is correlated with income. Thus, when income grows over time, total travel time will also change. Hence, there may be a potential endogeneity problem and empirical work should control for this effect when the objective is to estimate the income elasticity of VTTS. However Swedish data suggest that the average daily commuting time was 39.7 minutes in 1981 and 39.4 minutes ten years later⁶. Hence, the commuting time is remarkably stable over time and this problem should not be relevant for this paper.⁷

The major drawback of most previous studies is that they are conducted on a cross-sectional sample and that the policy relevant elasticity to use in CBA is the inter-temporal one⁸. Although some meta-analyses which take care of

⁶These figures were obtained from the Swedish Level of Living Survey, which is a longitudinal data set containing a representative sample of the Swedish population (see Erikson and Åberg, 1987).

⁷Another reason stated by Fosgerau (2005) is that the parametric assumption of the model may not be fulfilled and the estimates, thus, are not consistent. However, a semi-parametric approach is not applied in this paper.

⁸At least when the VTTS benefit is going to be adjusted over time in a CBA. The cross-sectional variation of the VTTS with respect to income might be used as a source for income differentiation of the VTTS used for policy. Still, this problem is beyond the purpose of this paper.

the inter-temporal dimension exist (e.g. Wardman, 2001, 2004 and Shires and De Jong, 2006), no study uses panel data on the individual level to this end. Here, my study plays an additional role for the determination of an appropriate inter-temporal income elasticity for the VTTS. In addition, the income variable is not given in intervals and defined after tax in this study meaning avoidance of the problem of Axhausen et al. (2006) and working in favor of one of the important points in Fosgerau (2005).

In Sweden, the praxis is to not adjust the VTTS in a CBA over time with respect to expected income increases during the economic life time of the project⁹. Instead, the praxis is to use the VTTS of the base year for all years within a project. However, new VTTS studies are not produced yearly, implying that the latest established VTTS is adjusted to the base year by using the change in GDP per capita. In this respect, Swedish praxis is still to use a unit inter-temporal income elasticity. (SIKA, 1999)

My objective of this paper is not to discuss whether Swedish praxis should be changed to adjust the VTTS with respect to expected income changes during the economic life time of the transport investments. The result of the present study may, however, have implications for how to revise the latest estimated VTTS up to the relevant base year.

⁹The motivation is due to the unambiguous impact an appreciation of the VTTS over time would have on the interest rate.

Some earlier evidence of the income elasticity of the VTTS in Sweden relies on data of the time valuation study of Algers et al. (1995). These data are purely cross-sectional and in their analysis there is a positive but rather weak relation between income and the VTTS. The estimated elasticity is 0.46 for single person households and concerning two person households, the elasticity is lower with respect to household income than with respect to individual income.

The variation in the VTTS of this Swedish study has been further analyzed (Lindqvist Dillén, 2003). She investigates the variation in the VTTS with respect to socio-economic variables for car trips. The results suggest that the lowest income group has a VTTS of 95 Swedish Crowns (SEK) per hour and that this value increases with 21 SEK per additional 100,000 SEK in income. This implies a relatively low income elasticity but the income variable is given as household income.

What income variable should then be used when the income elasticity of the VTTS is investigated? If the travel decisions are assumed to be made at the individual level and when the VTTS is derived from individual level data there is no compelling reason for using the household level of income. Furthermore, the VTTS in a CBA over time is usually changed with respect to the GDP per Capita. Fosgerau (2005), as mentioned earlier, argues that the relevant income variable should be after tax income since that is what can be used

for consumption. The empirical relationship between the individual after tax income and the VTTS can also be applied to the relationship between GDP per capita and VTTS if the factor shares of GDP are assumed to be roughly constant over time (Fosgerau, 2005).

Despite some advantages, the method used in this paper has a number of drawbacks as well. First, the VTTS is measured as the ratio between an individual's net wage premium and the individual's corresponding change in commuting time between two points in time. Clearly, this ratio can reflect other aspects than just a pure VTTS, for example may involuntary job changes be a problem in this respect. However, the rich data material used in this paper makes it possible to control for a large number of other individual variables that may affect this implicit VTTS. Furthermore, a number of different sample restrictions is made with the purpose to create a sample where the implicit VTTS is a good proxy as possible for the real VTTS. These sample restrictions are explained in more detail in subsection 3.2. Second, only job changers can be used in this study since non-job changers do not reveal a VTTS between two observation points. Also, some individuals will change job in a way that imply a dominant or dominated choice. This means that the VTTS will be negative for some individuals and the common assumption in the literature is that the VTTS distribution only consists of non-negative values. These types of sample

selection problems are discussed in subsection 3.3. Finally, the commuting variable is based on car trips and I do not know if the workers actually commute by car. However, most actual commuting times are likely to be highly correlated with the travel time for cars between the same places. In addition, one of the empirical sample specifications described in section 4 aim to assess this potential problem explicitly.

3 Methodology

In this section, I first present the model and definitions used in the paper. Then the data and definitions of variables are presented. Finally, some necessary sample restrictions and the sample selection problem are discussed.

3.1 Modeling the Income Elasticity of the VTTS

One of the special features of this study is the use of implicitly revealed individual VTTS as the dependent variable in the analysis, an approach that is inspired by the theory of compensated wage differentials. The assumption is that commuting time is a negative job characteristic which have to be compensated in the labor market by a higher wage to be accepted by the worker. For all workers that change job between time t and $t + 1$, the VTTS is defined as follows

$$VTTS_{i,t} \equiv \frac{w_{i,t+1} - w_{i,t}}{\tau_{i,t+1} - \tau_{i,t}} = \frac{\Delta w_{i,t}}{\Delta \tau_{i,t}}, \quad (1)$$

where w is the daily after-tax wage and τ is the daily commuting time. According to the conventional theory of the VTTS, it should always be positive since there is assumed to be a trade-off between the commuting time and the wage¹⁰. Ceteris paribus, to accept a longer commuting time, a higher wage have to be offered and vice versa.

Assume a random utility model specified as

$$U_{i,t} = \alpha_0 + \alpha_1 \tau_{i,t} + \alpha_2 w_{i,t} + \eta_{i,t}, \quad (2)$$

where η is a random individual-specific term and the VTTS is given by $-\alpha_1/\alpha_2$, i.e. the marginal rate of substitution between wage and commuting time. Taking the first difference of equation (2) and for convenience dropping the subscripts yields

$$\Delta U = \alpha_1 \Delta \tau + \alpha_2 \Delta w + \Delta \eta, \quad (3)$$

which can be solved for the definition of the VTTS in equation (1)

$$VTTS \equiv \frac{\Delta w}{\Delta \tau} = -\frac{\alpha_1}{\alpha_2} - \frac{\Delta \eta}{\Delta \tau \times \alpha_2}. \quad (4)$$

¹⁰Or in a traditional mode choice context between the travel time and the travel cost.

Here it can be seen that the VTTS as defined in this paper consists of the “true” VTTS and another individual-specific component.

Assume that the individual-specific part of equation (4) consists of both observable and unobservable heterogeneity

$$-\frac{\Delta\eta}{\Delta\tau \times \alpha_2} = f(w, \mathbf{x}, \mathbf{z}, \epsilon), \quad (5)$$

where \mathbf{x} is a vector of continuous variables and \mathbf{z} is a vector of discrete variables and ϵ is an error term. Furthermore, the assumptions are that $E[f(w, \mathbf{x}, \mathbf{z}, \epsilon)] = 0$ and that its variance is homoscedastic. The parametrization of the right-hand part of equation (5) is inspired by the specification in Wardman (2004)

$$f(w, \mathbf{x}, \mathbf{z}, \epsilon) = \delta w^\sigma \prod_{j=1}^n x_j^{\beta_j} e^{\mathbf{z}\gamma' + \epsilon}. \quad (6)$$

Inserting equation (6) in equation (4) yields

$$VTTS = -\frac{\alpha_1}{\alpha_2} - \delta w^\sigma \prod_{j=1}^n x_j^{\beta_j} e^{\mathbf{z}\gamma' + \epsilon}. \quad (7)$$

Now, taking the logarithm of equation (7) and again taking into account that the data is of individual level and have a time dimension the model can be rewritten as

$$\ln VTT S_{i,t} = \lambda + \sigma \ln w_{i,t-1} + \mathbf{x}_{i,t} \beta' + \mathbf{z}_{i,t} \gamma' + \epsilon_{i,t}, \quad (8)$$

where $\lambda = \ln(\alpha_1/\alpha_2) + \ln\tau$ and the inter-temporal income elasticity of VTTS is given by σ . Note also that the wage variable is given in period $t-1$. The reason for this is that the wage variable used as a regressor should not be included in the definition of the dependent variable, *VTTS*. Equation (8) is throughout the paper referred to as the basic model. The basic model is also varied in a number of ways to investigate the robustness of the results. The procedure hereof is described in connection to the results presented in section 4.

3.2 Data

The data set consists of administrative micro level data of employed individuals in Sweden randomly stock sampled in 1998. Included are also data of the same individuals in 1993, 1990 and 1986, conditional on being employed in all years respectively. This data is linked to an employee-level data set that identifies different establishments and their characteristics¹¹. This combination of data identifies the SAMS of both the residence and the establishment. From this, all workers' commuting time is imputed in the data by the use of a travel time matrix of all possible combinations of SAMS¹². Those travel times correspond to the fastest car trip between the central points of each SAMS according to the

¹¹Both these data sets are provided by Statistics Sweden (SCB).

¹²Data from the Swedish National Road Administration (SNRA).

contemporary speed limit.

Since the VTTS is implicitly revealed only by those individuals who change their job between two years of observation, I work with different definitions of job changers. The basic model definition is based on all individuals who have changed establishment during the interval. However, this also includes laid-off workers and they have probably not revealed an implicit VTTS. In the data, it is not possible to separate lay-offs from quits. Instead, I will also use two other definitions of job changers where the first one excludes those workers whose establishment have ceased to exist during the interval whereas the second one also excludes those workers whose establishment has decreased its number of employees during the interval.

The income variable used is the sum of employment income, self-employment income and compensations of labor related insurances. The income variable has to be inflated to be comparable over time. This is done by using a within sample inflating to take the job changing cost into account. The motivation is that workers change their job if their experienced utility minus the fixed job-changing costs is at least as high in the next job as in their current job. In other words, the workers' compensation to realize a job change have to cover these fixed costs. Following this line of argument, the inflating is made within each sample for the different specifications of job changers respectively. Finally, all

income variables are inflated to the money value of 1998.

The income variable is the pre tax income so to arrive at the individual net income the variable needs to be recalculated according to the relevant tax rules. The Swedish income tax system is rather complicated and was reformed in 1990. Fortunately, the post-reform income tax system consists of basically three different tax intervals; one basic deduction, one interval of a local tax and one interval of both a local tax and a national tax. For simplicity, this system is also applied on the income in 1986¹³. In addition, the local tax is specific to each municipality. Still the difference is not huge and for simplicity, I use the average local tax in 1998 of 31.65 percent for all municipalities in all observation years. The threshold value for paying the national tax was a yearly taxable income of 213,100 Swedish Crowns (SEK) in 1998. An additional complication of the system, is that the basic deduction changes with the income. Still these changes occur only for low and medium levels of yearly income and I will use the lowest level of basic deduction in 1998 of 10,700 SEK for all individuals¹⁴.

The VTTS variables is calculated as the ratio of the wage change between two years of observation and the corresponding change in commuting time. Since

¹³One reason for this strategy is that, prior to the reform, the capital income and labor income were brought together and taxed in the same system. Applying this to my data will probably lead to severe measurement errors since capital income is not observed.

¹⁴This will hardly be a problem in my study since all individuals in the estimation samples earn above a threshold value to ensure that they are full-time workers and then the basic deduction will be 10,700 SEK for most of the workers. More about the sample restrictions later in this subsection.

the wage variable is given yearly and the commuting time variable in minutes per working trip the wage variable is divided by 220, i.e the estimated number of working days during a year and the commuting variable is multiplied by 30 to be defined in hours per working day. Hence, the result will be a VTTS variable that is measured in SEK per commuting hour.

The control variables in period t are the following ones and they are the same in all specifications: commuting time, squared commuting time, age, gender, indicator variable of marriage, number of children between 0 and 6 years of age, number of cars in the household, county of residence and indicator variables of the education level. In addition, a number of changes in the individual characteristics during the interval is also used since it may affect the implicit VTTS. Those include: change of educational attainment, change of marital status and change of the number of children between 0 and 6 years of age. Job characteristics are captured by indicator variables of both the sector and the industry. When applicable, an indicator variable of the time period is also used in the estimation. Finally, a measure of accessibility to other jobs are defined from the following formula

$$\text{Accessibility}_j = \sum_{k=1}^K e^{-c_{jk}}(X_k), \quad (9)$$

where c_{jk} is the commuting time between SAMS area j and k and X_k is the

number of jobs in area k .

The sample used in the paper has to be restricted in several ways to make it possible to estimate the income elasticity of the VTTS. First of all, the income variable is given on a yearly basis without any information about the number of working hours. Since the income change between two observation periods is used to compute the VTTS variable it is necessary that the income change is not driven by a change in working hours. Hence a lower threshold value of the income have to be set where the workers with a lower yearly income is assumed to be working part-time. From data of SCB, the occupation with the lowest full-time income in 2005 had a average monthly pre tax wage of 16,500 SEK which yields a yearly income of 198,000 SEK. Furthermore, the overall average wage in 2005 was 24,300 SEK while it was 18,600 in 1998. Using these average wages as the input for deflating leads to a threshold value of the yearly income of 151,500 SEK in terms of incomes in 1998. This threshold value is considerably high since deflating by the average wages should imply a high deflating value and that the income increase during these years probably is higher for high income earners. Also, by using the average wage as the threshold value may be considered as using a fairly high value since some workers probably had a lower yearly income and still was working full-time. However, this conservative attitude follows from that it will be better to exclude a worker that is working

full-time than include a worker that is working part-time.

Furthermore, the commuting time variable in some cases takes values that are totally unrealistic. The reason is probably that some people commute weekly, have double residences, are distance working or are registered to an establishment that is not their actual one. Hence an upper threshold value of commuting time is set to minimize the probability that the workers do not commute this distance every working day. This threshold value is set to three hours per working day.

Except changing job, there is another way of adjusting the commuting time, i.e. move to another residence. The problem is that a change of residence do not affect the wage rate which results in a distortion of the implicit VTTS. Hence all workers that change residence in the given interval are excluded from the sample. Change of residence is measured as living in another SAMS in period t compared to in period $t + 1$ ¹⁵.

The estimation sample has to be restricted with respect to the VTTS variable as well. First of all, some individuals has chosen a dominating or dominated alternative when changing job implying that the VTTS is negative in these cases. The assumption of all relevant literature is that the VTTS distribution only take positive values and, thus, these observations are excluded.

¹⁵There is also a possibility that individuals move within a SAMS. Recall, however, that the SAMS are relatively small areas and a move in this case is most likely not caused by a willingness to adjust the commuting time.

Furthermore, the commuting time change may be considerably small and/or the income change considerably large leading to an implausible high VTTS. It is very unlikely that commuters are willing to pay remarkably high values to reduce the traveling time. Considering this argument as well as the potential problem of outliers, all observations with a VTTS higher than 1,000 SEK per hour are excluded from the estimation sample. Finally, there are some workers that when changing job still works in the same SAMS. In these cases, the change in commuting time is calculated to zero implying that the implicit VTTS is not defined and consequently these observations can not be included in the estimations. However, the number of observations excluded for this reason is relatively small.

With a variety of sample restrictions made it is necessary to devote a subsection to the problem of sample selection and the possibilities to deal with this problem.

3.3 Sample Selection Problems

In this application, as described above, sample selection problems arise in several different steps which cause a lot of lost observations. Problems with sample selections may arise if there is systematic differences between job changers and non-job changers, since only the former are included in the estimation. Secondly, a relatively large fraction of the job changers has a negative VTTS. This may be

caused by unobserved heterogeneity as individual changes in the labor conditions during the given time interval, for example unobserved changes in working hours due to part-time retirement, part-time studying or parental leave. Finally, there may also be a systematic difference between those who change residence in the time interval and those who not.

In tables 1 and 2, summary of statistics for the sample restricted only with respect to the threshold values of income and commuting time and the basic estimation sample with the restrictions outlined above is presented respectively. As one can see, there is a dramatic decrease in the number of observations from about 180,000 to approximately 18,000. When examining the differences of the means across the groups, it is clear that several variables have a higher mean for the estimation sample observations. This is specifically true for net income, commuting time, the dummy for being married and the number of cars in the household. Presumably, the higher mean of these variables in the selected group are connected, since commuting time usually is longest for high-earning workers. Furthermore, married people and people with a high income should have more cars in the household. More cars in the household may also imply less restrictions in the commuting possibilities and hence be important for the length of the commuting. Finally, the mean of the implicit VTTS in the basic estimation sample is taking the plausible value of 57 SEK per hour.

[Insert table 1 about here]

[Insert table 2 about here]

To empirically check the consequences of the sample restrictions, a various set of different sample and model specifications is used as sensitivity analyses. One of them is the basic model extended to a Heckman selection model which take the sample selection problem explicitly into account and produces consistent estimates. The procedure is to first estimate the selection equation, i.e. the probability of being included in the basic estimation sample by a probit model, and then the outcome equation using the inverse of the Mill's ratio from the first step as an independent variable (Cameron and Trivedi, 2005). For simplicity and since no economic theory guiding can be applied here, the same variables are used in the selection equation as in the second step outcome equation. An approach like this may seem to induce identification problems, but the model is identified given that normally distributed errors are assumed (Cameron and Trivedi, 2005).

All estimations are performed by ordinary least squares (OLS) except for the sample selection extension described above which is estimated by maximum likelihood. Furthermore, Stata is used for all estimations and all results are based on robust standard errors.

4 Empirical Results

In table 3, the results from the basic model are presented. The income elasticity is estimated to 1.06 which is not significantly different from unity, since the p -value of such a test is as high as 0.45. Furthermore, the effect of the commuting time is increasing at low values, reach its maximum at the commuting time of 6.9 minutes per trip¹⁶ and then starts to decline. This value is rather low since the VTTS usually is found to increase with the travel time. The period of 1990 to 1993 have a significantly lower VTTS than the period of 1993 to 1998. This may reflect the large recession in the Swedish economy during the beginning of the 90's. The VTTS is also found to be increasing with age and decreasing with the accessibility to other jobs. Also, if the individual is divorced during the period the VTTS is lower, while the VTTS is higher if the number of children under age 6 is increased during the period. All other control variables, including gender, are non-significant¹⁷. The R -squared of 0.13 is fully acceptable when considering the micro level feature of the data.

[Insert table 3 about here]

This basic model is extended in various ways and only the results regarding

¹⁶Calculated by $\exp(\frac{-1.746}{2 \times 0.452})$.

¹⁷The estimation also includes indicator variables for education, sector and industry. However, they are difficult to interpret and are not presented in the paper. These coefficients can be provided from the author upon request.

the income elasticity and other exceptional results are interpreted. The results from including a second lag of the net income variable are presented in table 4. In this case the elasticity is measured by the sum of both income variables and can be viewed as a long-run elasticity. The difference compared to the basic result is minor and the p -value for the hypothesis of an income elasticity of unity is 0.54. In table 5, the results from a model including only the second lag of the income are presented. Here, the estimated income elasticity is lower than unity, but still not significantly different with a p -value of 0.30.

[Insert table 4 about here]

[Insert table 5 about here]

In table 6, the basic model is extended to only include the period of 1993 to 1998. The reason is to check the sensitivity of using the post-reform act to calculate the net income variable in 1986, i.e. prior the tax reform. However, this extension has basically no effect on the estimated result. In fact, the estimated income elasticity is almost as close as unity as it might be and the p -value is 0.96.

[Insert table 6 about here]

Table 7 presents the results where the sample is restricted to only men which have at least one car in the household. This is performed to control for the potential effect that the commuting time variable based on traveling times by car is suffering from measurement errors. The argument for using only men is that they are more likely to commute by car than women¹⁸. The estimated elasticity increases in this specification, although it is still far from being significantly different from one.

[Insert table 7 about here]

In table 8, the individuals whose establishment ceases to exist during the period are excluded and in table 9, this extension is further developed to also exclude individuals whose establishment decreased the number of employees during the period. None of these extensions, however, result in an income elasticity significantly different from unity.

[Insert table 8 about here]

[Insert table 9 about here]

Finally, in table 10, the results of the Heckman selection model are presented. Neither here is the estimated elasticity significantly different from unity. How-

¹⁸This argumentation is in line with the result of Transek (2006).

ever, the estimated lambda parameter, i.e. the inverse of the Mill's ratio which is summarizing the selectivity effect, is positive and significant. Hence there is a selection effect in the basic model but the effect on the income elasticity is only modest.

[Insert table 10 about here]

5 Conclusions

The purpose of this paper was to estimate the inter-temporal income elasticity of the value of travel Time Savings (VTTS) on Swedish revealed preference data. For all job changers an implicit individual VTTS is calculated based on the theory of compensated wage differentials and then this VTTS is used as a dependent variable in the analysis. Furthermore, the basic sample used in the analysis has to be restricted in several ways addressing the problem with sample selection which are rigorously treated throughout the paper.

The basic estimation results suggest an income elasticity that is not different from unity. In addition, all types of sensitivity analysis by defining different estimation samples or models also produce similar results. Hence, this paper corroborate the findings of Fosgerau (2005) and further confirms his arguments that using the net income in a progressive tax system may imply an income

elasticity of the VTTS not different from unity.

Finally, a Heckman selection model indeed finds a selection effect but the income elasticity is neither significantly changed in this model specification. Hence, the conclusion is that the estimated results show no evidence at all that the inter-temporal income elasticity of the VTTS in Sweden is less than one.

References

- Algers, S., B. Hugosson, and J. Lindqvist Dillén: 1995, '1994 års tidsvärde-studie'. Slutrapport, Transek AB, Solna, Sweden.
- Axhausen, K. W., S. Hess, A. König, G. Abay, J. J. Bates, and M. Bierlaire: 2006, 'State of the Art Estimates of the Swiss Value of Travel Time Savings'. Working paper, Institute for Transport Planning and Systems, ETH Zürich.
- Becker, G. S.: 1965, 'A Theory of the Allocation of Time'. *Economic Journal* **75**(299), 493–517.
- Cameron, A. C. and P. K. Trivedi: 2005, *Microeconometrics: Methods and Applications*. New York: Cambridge University Press.
- Erikson, R. and R. Åberg: 1987, *Welfare in Transition - Living Conditions in Sweden 1968-1981*. Oxford: Clarendon Press.
- Fosgerau, M.: 2005, 'Unit Income Elasticity of the Value of Travel Time Savings'. Working paper, Danish Transport Research Institute.
- Fosgerau, M.: 2006, 'Investigating the Distribution of the Value of Travel Time Savings'. *Transportation Research - Part B* **40**(8), 688–707.
- Gunn, H.: 2001, 'Spatial and Temporal Transferability of Relationships between Travel Demand, Trip Cost and Travel Time'. *Transportation Research - Part E* **37**(2-3), 163–189.
- Heatco: 2006, 'Main Principles for Harmonized Guidelines for Infrastructure Project Appraisal'. 6th framework research programme, European Commission.
- Hensher, D. A. and A. Brewer: 2001, *Transport - An Economics and Management Perspective*. Oxford: Oxford University Press.

- Hensher, D. A. and P. Goodwin: 2004, 'Using Values of Travel Time Savings for Toll Roads: Avoiding Some Common Errors'. *Transport Policy* **11**, 171–181.
- Lindqvist Dillén, J.: 2003, 'Variation in the Value of Travel Time'. Ph.D. thesis, Department of Infrastructure, Royal Institute of Technology, Stockholm, Sweden.
- McFadden, D.: 1974, *Frontiers in Econometrics*, Chapt. Conditional Logit Analysis of Qualitative Choice Behavior. New York: Academic Press.
- Rosen, S.: 1986, *Handbook of Labor Economics*, Vol. 1, Chapt. The Theory of Equalizing Differences. Amsterdam: North-Holland.
- Shires, J. D. and G. C. De Jong: 2006, 'An International Meta-Analysis of Values of Time'. Annex a, Report to Heatco.
- SIKA: 1999, 'Översyn av samhällsekonomiska kalkylprinciper och kalkylvärden på transportområdet - ASEK'. Report 1999:6, SIKA, Stockholm, Sweden.
- Transek: 2006, 'Jämställdhet vid val av transportmedel'. Slutrapport 2006:22, Transek AB, Solna, Sweden.
- Wardman, M.: 2001, 'A Review of British Evidence on Time and Service Quality Valuations'. *Transportation Research - Part E* **37**(2), 107–128.
- Wardman, M.: 2004, 'Public Transport Values of Time'. *Transport Policy* **11**, 363–377.

Table 1: Descriptive statistics of the sample restricted to yearly income above 151 500 SEK and commuting time below 90 minutes per trip.

Variable	Mean	(Std. Err.)
Net income in SEK per year	191,931	(60,427)
Commuting time in minutes per trip	11.22	(11.05)
Age	36,4	(8.42)
Married	0.61	
No of children	0.33	(0.67)
No of cars in household	1.02	(0.60)
Accessibility	6.5	(1.8)
Eduction changed	0.01	
Getting married	0.04	
Getting divorced	0.03	
More children	0.08	
Less children	0.14	
Female	0.29	
No of observations	178,370	

Standard errors are not presented for the dummy variables since they are determined by the mean according to $\sqrt{\mu(1-\mu)}$.

Table 2: Descriptive statistics of basic estimation sample. 8.

Variable	Mean	(Std. Err.)
Net income in SEK per year	197,398	(61,259)
Commuting time in minutes per trip	14.45	(12.81)
Age	36.3	(7.93)
Married	0.66	
No of children	0.39	(0.71)
No of cars in household	1.04	(0.62)
Accessibility	6.4	(1.85)
Eduction changed	0.02	
Getting married	0.04	
Getting divorced	0.02	
More children	0.07	
Less children	0.17	
Female	0.31	
VTTS	56.67	(126)
No of observations	17,912	

Standard errors are not presented for the dummy variables since they are determined by the mean according to $\sqrt{\mu(1-\mu)}$.

Table 3: Estimation results of basic model as given in equation 8.

Variable	Coefficient	(Std. Err.)
Net income $_{t-1}$	1.059**	(0.078)
ln Commuting time	1.746**	(0.060)
(ln Commuting time) ²	-0.452**	(0.013)
Period 90-93	-0.507**	(0.078)
Age	0.006*	(0.002)
Married	0.020	(0.033)
No of children	0.025	(0.033)
No of cars in household	0.012	(0.024)
Accessibility	-0.034**	(0.009)
Eduction changed	-0.060	(0.111)
Getting married	0.070	(0.080)
Getting divorced	-0.187*	(0.086)
More children	0.192**	(0.059)
Less children	-0.042	(0.058)
Female	0.025	(0.035)
Intercept	-11.532**	(0.947)
P-value for test of income elasticity = 1		0.452
No of observations		17,912
R ²		0.132

The estimation also include indicator variables for education, working sector, working business and county of residence. **, * and † denotes significance on the one- five- and ten-percent level respectively.

Table 4: Basic model extended to also include the second lag of the net income.

Variable	Coefficient	(Std. Err.)
Net income _{t-1}	0.848**	(0.180)
Net income _{t-2}	0.236	(0.187)
ln Commuting time	1.792**	(0.110)
(ln Commuting time) ²	-0.458**	(0.022)
Age	0.010*	(0.004)
Married	-0.068	(0.056)
No of children	-0.010	(0.065)
No of cars in household	0.052	(0.040)
Accessibility	-0.055**	(0.014)
Eduction changed	-0.129	(0.214)
Getting married	-0.041	(0.144)
Getting divorced	-0.078	(0.137)
More children	0.192	(0.119)
Less children	-0.008	(0.104)
Female	0.034	(0.062)
Intercept	-11.652**	(1.637)
P-value for test of income elasticity = 1		0.537
No of observations		6,660
R ²		0.160

The estimation also include indicator variables for education, working sector, working business and county of residence. **, * and † denotes significance on the one- five- and ten-percent level respectively.

Table 5: Basic model extended to only include the second lag of the net income.

Variable	Coefficient	(Std. Err.)
Net income _{t-2}	0.866**	(0.128)
ln Commuting time	1.792**	(0.110)
(ln Commuting time) ²	-0.457**	(0.023)
Age	0.009*	(0.004)
Married	-0.058	(0.056)
No of children	-0.013	(0.065)
No of cars in household	0.053	(0.040)
Accessibility	-0.053**	(0.014)
Education changed	-0.109	(0.213)
Getting married	-0.042	(0.144)
Getting divorced	-0.072	(0.137)
More children	0.192	(0.120)
Less children	-0.013	(0.105)
Female	0.010	(0.061)
Intercept	-9.018**	(1.547)
P-value for test of income elasticity = 1		0.298
No of observations		6,660
R ²		0.157

The estimation also include indicator variables for education, working sector, working business and county of residence. **, * and † denotes significance on the one- five- and ten-percent level respectively.

Table 6: Basic model extended to only include time period 93-98.

Variable	Coefficient	(Std. Err.)
Net income $_{t-1}$	0.994**	(0.111)
ln Commuting time	1.730**	(0.090)
(ln Commuting time) ²	-0.444**	(0.019)
Age	0.009**	(0.003)
Married	-0.026	(0.048)
No of children	-0.005	(0.052)
No of cars in household	0.066 [†]	(0.034)
Accessibility	-0.044**	(0.013)
Eduction changed	-0.029	(0.172)
Getting married	0.054	(0.105)
Getting divorced	-0.120	(0.110)
More children	0.210*	(0.086)
Less children	-0.004	(0.087)
Female	-0.027	(0.050)
Intercept	-10.664**	(1.329)
<hr/>		
P-value for test of income elasticity = 1	0.957	
No of observations	8,917	
R ²	0.150	

The estimation also include indicator variables for education, working sector, working business and county of residence. **, * and [†] denotes significance on the one- five- and ten-percent level respectively.

Table 7: Basic model extended to only include men with at least one car in the household.

Variable	Coefficient	(Std. Err.)
Net income _{t-1}	1.127**	(0.106)
ln Commuting time	1.863**	(0.084)
(ln Commuting time) ²	-0.467**	(0.018)
Period 90-93	-0.653**	(0.108)
Age	0.002	(0.003)
Married	-0.054	(0.049)
No of children	-0.005	(0.043)
No of cars in household	0.061	(0.045)
Accessibility	-0.036**	(0.012)
Education changed	-0.112	(0.169)
Getting married	-0.005	(0.117)
Getting divorced	-0.168	(0.130)
More children	0.107	(0.082)
Less children	-0.049	(0.073)
Intercept	-12.333**	(1.285)
P-value for test of income elasticity = 1		0.231
No of observations		9,488
R ²		0.143

The estimation also include indicator variables for education, working sector, working business and county of residence. **, * and † denotes significance on the one- five- and ten-percent level respectively.

Table 8: Basic model extended to exclude workers whose establishment ceased to exist during the time period.

Variable	Coefficient	(Std. Err.)
Net income $_{t-1}$	0.944**	(0.093)
ln Commuting time	1.690**	(0.075)
(ln Commuting time) ²	-0.451**	(0.016)
Period 90-93	-0.546**	(0.091)
Age	0.010**	(0.003)
Married	-0.018	(0.038)
No of children	0.034	(0.038)
No of cars in household	-0.009	(0.029)
Accessibility	-0.043**	(0.010)
Education changed	0.006	(0.121)
Getting married	0.115	(0.092)
Getting divorced	-0.104	(0.107)
More children	0.114	(0.070)
Less children	-0.036	(0.067)
Female	0.033	(0.041)
Intercept	-9.798**	(1.956)
<hr/>		
P-value for test of income elasticity = 1	0.549	
No of observations	12,823	
R ²	0.148	

The estimation also include indicator variables for education, working sector, working business and county of residence. **, * and † denotes significance on the one- five- and ten-percent level respectively.

Table 9: Basic model extended to exclude workers whose establishment has decreased its employment during the time period.

Variable	Coefficient	(Std. Err.)
Net income $_{t-1}$	0.731**	(0.171)
ln Commuting time	1.466**	(0.135)
(ln Commuting time) ²	-0.389**	(0.028)
Period 90-93	-0.962**	(0.185)
Age	0.008	(0.005)
Married	0.041	(0.068)
No of children	0.074	(0.065)
No of cars in household	-0.038	(0.050)
Accessibility	-0.056**	(0.018)
Education changed	-0.401	(0.250)
Getting married	0.161	(0.143)
Getting divorced	-0.027	(0.183)
More children	0.134	(0.112)
Less children	-0.119	(0.115)
Female	-0.009	(0.073)
Intercept	-9.122**	(2.086)
<hr/>		
P-value for test of income elasticity = 1	0.116	
No of observations	4,118	
R ²	0.171	

The Estimation also include indicator variables for education, working sector, working business and county of residence. **, * and † denotes significance on the one- five- and ten-percent level respectively.

Table 10: Heckman selection estimation of the basic model.

Variable	Coefficient	(Std. Err.)
Net income _{t-1}	1.068**	(0.078)
ln Commuting time	1.766**	(0.060)
(ln Commuting time) ²	-0.453**	(0.013)
Period 90-93	-0.507**	(0.078)
Age	0.006*	(0.002)
Married	0.028	(0.033)
No of children	0.026	(0.033)
No of cars in household	0.013	(0.024)
Accessibility	-0.033**	(0.009)
Eduction changed	-0.047	(0.111)
Getting married	0.067	(0.080)
Getting divorced	-0.210*	(0.086)
More children	0.181**	(0.059)
Less children	-0.036	(0.058)
Female	0.027	(0.035)
Intercept	-11.797**	(0.948)
lambda	0.094*	(0.036)
P-value for test of income elasticity = 1	0.383	
No of observations	178,370	
Log-likelihood	-90995.853	

The Estimation also include indicator variables for education, working sector, working business and county of residence. **, * and † denotes significance on the one- five- and ten-percent level respectively. Results from the selection equation are provided by the author upon request.