An international meta-analysis of values of travel time savings

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Abstract

Values of travel time savings are often used in cost-benefit analysis of transport projects and policies, and also to compute generalised travel costs. There has been considerable debate as to whether different research methods (e.g. stated versus revealed preference) will lead to different values of travel time savings, and which segmentations (e.g. by income or mode) are most important to capture the heterogeneity in these values. In addition there are many countries where no specific valuation studies have been done. In this paper new equations are estimated on the outcomes of value of travel time savings studies from various countries. In the data set, several countries appear more than once, which is taken into account by estimating random effects panel models. The meta-analysis sheds some new light on the variation of the value of travel time savings by income, country, travel purpose, mode, distance and by survey method. Furthermore, the resulting meta-models are applied to produce new values of travel time savings for business travel, commuting and for other purposes in passenger transport, for 25 European Union Member states. Similar methods could be used to statistically analyse studies carried out on other non-monetary effects, both for transport and non-transport projects, and for inclusion in cost-benefit analysis.

Keywords: Values of travel time savings; meta-analysis; European Union; business travel; commuting.

1. Introduction

The value of travel time savings (VTTS) is a key concept in transport modelling and transport project appraisal (see Gunn, 2008). It is mainly used for two different purposes. On the one hand, it is an input into the cost-benefit analysis of infrastructure projects, facilitating the comparison of the time savings for travellers (and freight), as caused by the project, against other attributes, such as the investment cost. This is often the largest benefit of a transport project. On the other hand, the value of travel time savings is also used in traffic forecasting models, in which one of the explanatory variables is a linear combination of travel time and cost, called 'generalised cost'. Different methods can be used to derive the VTTS (see for instance Daly, 1996), including models on stated preference (SP) and on revealed preference (RP) information, and the cost savings or resource costs approach that uses (a fraction of) the wage rate as the VTTS. There is considerable debate on the influence of the choice of method on the VTTS outcomes (e.g. Brownstone and Small, 2002, Wardman, 2004). Another issue is which segments (e.g. segmentation by income, travel purpose and/or mode) should be used to capture heterogeneity in the VTTS. In this paper, new insights on both issues will be derived from a meta-analysis of previous VTTS studies.

Meta-analysis can be defined as: the statistical analysis of analyses. A number, usually large, of previous research studies (the Greek word 'meta' means 'after') is analysed using statistical methods. The first meta-analysis was performed in 1904 by Karl Pearson, who proposed the analysis of results from a group of studies to allow more accurate data analysis while attempting to overcome the problem of reduced statistical power in studies with small sample size. Meta-analysis is widely used now in epidemiology and medicine, where often large numbers of studies, carried out in similar ways (e.g. double-blind treatment experiments), are available on some topic, and where meta-analysis has proven to be a valuable tool for synthesising the available research outcomes. The term 'meta-analysis' was coined by Glass only in 1976.

Meta-analysis does not use the data sets of the individual studies, but analyses a data set at a higher level. What meta-analysis does is to look for patterns in the outcomes of past studies by using statistical methods, e.g. by regressing their findings on variables such as: attributes of the countries where the study took place, the segments of the population studied and the method used. General introductions to meta-analysis are Glass et al. (1981), Hedges and Olkin (1985), Rosenthal (1991) and Button et al. (1999).

Once such a regression has been carried out, the results can be used in two different ways. First, the outcomes of the meta-analysis can be used for interpreting the outcomes of the individual past studies and for reaching conclusions from the overall evidence that would not be possible from a single or small set of studies, or from just taking averages from a large set. This is because a meta-analysis synthesises many studies and shows new overall and multi-dimensional patterns. Secondly, the estimation results from a meta-analysis can be used for predicting other situations. In the case of value of travel time savings (VTTS) studies, a meta-regression can be estimated on study outcomes for countries where VTTS studies have been carried out, and then applied to countries (using explanatory variables for these countries) where such studies are lacking. Meta-analysis has been applied in transport research, though not very often. In section 2 of this paper we briefly review applications of meta-analysis in transport.

This paper presents the results of a meta-analysis of studies on the VTTS, focussing on national passenger VTTS studies across the world. Similarly to Wardman (2004) in his meta-analysis for UK VTTS studies only, and unlike Button (1995) and Zamparini and Reggiani (2007b) who had fewer VTTS observations in their meta-regressions, we obtain statistically significant results for a considerable number of explanatory variables (journey purpose, mode, GDP per capita, distance class, country group, type of study, time period). Unlike previous studies in transport, we take account of the panel nature of the data (several countries are in the data set multiple times: different VTTS studies in different years) by estimating random effects models. In section 2, we review previous meta-analyses in transport. The data set used is described in section 3. The estimated models and the estimation results are in section 4. In section 5, the estimated models are applied to data for the 25 EU countries to obtain a new VTTS for different travel purposes and modes. Section 6 contains a summary and recommendations for further research.

2. Meta-analysis in transport

Button (1995) was probably the first to advocate the use of meta-analysis in transport research trying to go beyond traditional literature reviews that just list findings of previous papers, and to learn more from sets of individual studies. However, even in a good meta-analysis, sources of bias in the original studies cannot be controlled for, and meta-analysis therefore cannot reach sound conclusions when the underlying material was badly designed. Button provided some illustrations of meta-analysis in transport: applications to the VTTS, traffic noise and the impact of transport projects on land use. In his illustration on the VTTS, he used 29 observations and explained the

VTTS from travel purpose, mode and country group in a linear regression. None of these variables emerged as statistically significant, which may have been due to the small sample size.

Meta-analysis has been used to study public transport demand elasticities, using a non-parametric statistical method called rough set analysis, on data from twelve studies (Nijkamp and Pepping, 1998). This shows that meta-analysis is not a single technique (e.g. regression analysis), but an analytical approach that comprises different methods.

Kremers et al. (2000) also applied meta-analysis to explain price elasticities of transport demand (various modes) using data from 24 studies. In this application, a regression analysis was carried out.

Blaeij et al. (2003) carried out a meta-analysis to study the value of statistical life in road safety. This was based on 30 individual studies (using a revealed preference, stated preference or contingent valuation approach) providing 95 values of changes in the level of exposure to traffic risks. They used regression analysis explaining the natural logarithm of the value of statistical life. The main analysis did not weight studies. In meta-studies in medicine, where there are often many individual studies applying similar experimental set-ups, statistical methods and reporting protocols, it is not uncommon to weight the individual studies by the inverse of their variance. In transport analysis, the methods used and reporting conventions are considerably less standardised. Information on the variance is often not reported. This makes weighting studies very difficult. Blaeij et al. performed a weighted regression on a subset of the data for which they had information on sample size, using sample size (which is inversely related to variance) as weight.

In de Jong et al. (2004a), outcomes of runs with various national models were used to develop a model for the whole of the European Union to generate transport demand forecasts (passengers and freight).

In the UK, meta-analysis has been performed on VTTS studies (Wardman, 2004) and fare elasticities (Wardman and Shires, 2004). Wardman used 171 local, regional and national passenger VTTS studies from the UK only, giving 1167 observations, and performed a regression analysis explaining the natural logarithm of the VTTS. This study obtained many significant coefficients (travel purpose, mode, distance class, GDP, stated versus revealed preference). Wardman and Shires (2004) used 902 public transport fare elastiticies obtained from 104 studies conducted in Britain between 1951 and 2002. The markets covered were inter-urban rail travel, suburban rail travel, urban bus travel and London underground and a number of fare elasticities were predicted that varied by type of mode, journey type and travellers. Comparisons with existing studies suggest that the results derived from the meta-analysis might prove a useful tool for the estimation of fare elasticities where it is not possible to estimate them by direct methods.

Zamparini and Reggiani (2007a) assembled 46 observations on the VTTS in freight transport for 22 countries in Europe and North America. They estimated a regression function that explained the natural logarithm of the VTTS , and obtained significant estimates for GDP per capita, region and mode.

The same authors also carried out a meta-analysis for the VTTS in passenger transport (Zamparini and Reggiani, 2007b). They used 90 observations on the VTTS from 53 studies (Europe, North America, Australia) and explanatory variables such as GDP per capita, region, year of study, trip purpose and mode in a linear regression. The only significant coefficient (at 5%) that they obtained was a dummy for travelling on employer's business.

3. The data sets used

To some degree, the data collection for this meta-analysis builds on earlier data collection efforts (e.g. TRACE, 1998; de Jong et al, 2004b) although several recent studies have been included as well. A total of 77 studies were collected (some investigating one specific mode, some with multiple modes), producing 1,299 values of travel time savings in total. A study can provide several values of travel time savings, e.g. for different travel purposes, population groups and/or travel modes. The 77 studies cover 30 countries around the world, mainly OECD countries, with some emphasis on European countries.

An important part of a meta-analysis is the collection of the data-set, including rules for inclusion and exclusion of individual studies. The data set should form a sample that is representative for the phenomenon of interest (here the VTTS in passenger transport) and the individual observations from the studies included should be representative for their situation (e.g. country). One of the problems here is that of publication bias. Statistically significant results are more likely to make it to the professional journals and books than non-significant results. Rosenthal (1991) calls this the 'file drawer' problem: the journals are filled with the 5% of studies that show significant values, while the file drawers back at the lab are filled with the other 95% of the studies that show non-significant results. Likewise, values that are much higher or lower than generally accepted may be harder to get published. In the study of the VTTS it is not the case that the majority of studies carried out finds non-significant values, but there may be a tendency in the published literature to accept studies that confirm accepted wisdom on what the VTTS should be. A partial solution to this problem is to also include values from the 'fugitive' literature (consultancy reports, unpublished research memoranda). This has also been done in the data collection for this paper. In order to obtain data points which are representative for their countries, we tried to make use of national-level value of time studies and results as much as possible. In order to check for publication bias we produced funnel plots. In Figure 1 is the funnel plot for the commuting VTTS against sample size. Sample size was only reported for a small subset of the studies. If there would be no publication bias, the funnel plot would be roughly symmetrical: the outcomes of the smaller studies fall on both sides of the ones for the larger (more precise) studies. In Figure 1 we can see that the funnel plot is reasonably symmetrical, as would be the case without publication bias.

The sample as a whole can be thought of as representative for high-income countries and to some degree for middle-income countries; only a few middle income countries were included and no low-income countries. The research focussed on national studies (so we did not re-use Wardman's data set with its many local/regional UK studies) and on recent studies (defined as 1990 and later; only for a few countries that had limited recent material did we use older studies) and studies for which we could get information on VTTS as well our explanatory variables . The distribution of values across countries is given in the Appendix.

We brought all the data into a common format:

- The VTTS are in 2003 Euros. We used currency exchange rates and national price indices; with regards to market or factor prices[1], we use the units as in the original surveys; generally speaking non-work values are in market prices and the work values are in factor prices. Purchasing power parities (PPP) were not used[2]. In our analysis, both the values of travel time savings and the GDP/capita used refer to the year of the original survey (but in 2003 prices). The GDP/capita information was taken from World Bank statistics; all other explanatory variables were taken from the original individual studies. Data plots revealed a large variation in VTTS, but no real outliers that would have needed to be removed before analysis.
- From the underlying studies a common set of explanatory variables on countries, segments of population, method used, year, etc was created (presence of such data was also among the study inclusion criteria). We choose to focus on travel purpose, income, type of study and mode of transport in this study, because some (not all) previous studies have shown these variables to be relevant for explaining differences in the VTTS and because in the literature there is considerable debate on the importance of these variables. Separate models were estimated for different journey purposes, whereas income, mode and type of study were tried as explanatory variables. In the three subsections of section 4.3

[1] Factor prices are the prices as received by the producers; market prices are the prices as paid by the consumers. The difference consists of taxes and government subsidies on production.

[2] In multiple country studies either market exchange rates (MXR) or purchasing power parity (PPP) exchange rates are used to make income data comparable across countries. The PPP method takes into account differences in the relative prices and quantities consumed of various products in the countries studied. Using per capita GDP at PPP exchange rates has the effect of raising per capita income of poorer countries relative to higher-income countries. We decided to use MXR here because PPP figures for different countries are known to be of varying –sometimes low- degree of reliability. MXR is more relevant for internationally traded goods and services and PPP more for local goods and services. In the EU, the former category is of increasing importance.

we shall discuss our outcomes for each of the three factors, to show what our results add to those in the literature.

- Only a few studies contained information on the statistical precision of the VTTS estimate. Therefore we cannot use such information for weighting the observations. Even information on sample size was not provided consistently, and for some studies and values (using the cost savings approach, where the value of travel time savings is assumed to be equal to the wage rate per hour or a specific percentage of this, e.g. Department for Transport, 2008) sample size is not a relevant issue, since the values need not be based on sample surveys. So sample size could not be used as an alternative for weighting by variance. We also did not try to put a quality judgement on the individual studies. Given the lack of standardisation in transport analysis methods, such a judgement is likely to be very subjective. The meta-analysis in the following sections was carried out without any weighting, which is the method used so far for all meta-analyses in transport, except some of the work reported in de Blaeij et al. (2003).

4 Estimation results

4.1 The random effects panel model specification

The data sets contain multiple observations for several countries (e.g. different studies for the same country or even different values for different purposes from the same study). One of the assumptions underlying ordinary least squares (OLS) regression is that the observations are not correlated. It is very likely however that observations from the same country will be correlated and that.the assumption of independent observations underlying OLS does not hold resulting in OLS estimation results that will be biased.

Panel data models can be used to take the correlation between observations from the same country into account and remove the bias. A panel is a data set with multiple respondents each of which are observed multiple times (e.g. a sample of persons is interviewed every year for five consecutive years). In our case, the ‘respondents’ are the different countries for which we have VTTS from several studies.

The general model is:

$$y_{it} = \mathbf{x}'_{it}\beta + u_{it} \qquad (1)$$

with y denoting VTTS, explanatory variables in **x**, coefficients to be estimated in β and error term u. The subscript i (i=1, 2, …, N) gives the countries and t the different observations (e.g. for different years) per country (t=1, 2, …, T). We have an unbalanced panel, meaning that the number of observations per country can differ between countries.

We can decompose the error term u into two components:

$$u_{it} = \mu_i + \varepsilon_{it} \qquad (2)$$

The first error component is country-specific (in a panel context this would be a cross-section-specific component), the latter is the usual identical and independent normally distributed error component (which it can be because of the presence of the first component that takes account of the correlation within a country).

There are two ways of estimating this panel model:

- The fixed effect model; which estimates a constant for every i (every country)

- The random effects model, which starts out by assuming a normal distribution for the first error component with a zero mean and a standard error to be estimated (one can also specify more complicated covariance structures).

Both models were estimated using Maximum Likelihood in SAS. The number of extra coefficients in the fixed effects model is equal to the number of countries minus one (so: 30 minus one). Even though the fixed effects model had a better fit, for this paper we selected the random effects model. In estimation most of the fixed effects were not significant. The random coefficients model on the other hand is much more parsimonious and has just one extra coefficient compared to ordinary least squares (OLS): this is either the variance or the standard error of the country-specific effect. For all three purposes, this coefficient was highly significant, and the loglikelihood is significantly higher than in the OLS model . The estimation results for the explanatory variables (not the country dummies) in the fixed effects model also were quite similar to those of the random effects model.

4.2 Estimation results by journey purpose

We tried different functional forms (linear, logarithmic, double logarithmic) and found that the best results (in terms of R^2, t-ratios, sign and size of coefficients) were obtained by using double logarithmic models. In these models, the dependent variable is the natural logarithm of the VTTS and the explanatory variables are the natural logarithm of GDP per capita (of the country and year studied) and a number of dummy variables. Wardman (2004) also found that this specification performed best in his regression analysis on UK VTTS studies. In these double logarithmic models, or constant elasticity of substitution models, the estimated coefficient for the natural logarithm of GDP per capita will be the GDP per capita (‘income’) elasticity of the VTTS.

In meta-analysis, especially in the health sciences, it is not uncommon to start the analysis by carrying out analysis of variance (ANOVA) or Q-tests to detect heterogeneity in the data. However, the Q-test (Hedges and Olkin, 1985) requires information on the variances of the VTTS, which is not available. ANOVA only provides binary comparisons, whereas regression analysis is a multivariate approach that deals with the influence of several factors on the VTTS at the same time, and also provides estimates of the coefficients for the influence of these explanatory factors. Therefore, we carried out our heterogeneity test using regression analysis directly. We started with a single model for all passenger trips, with dummy variables for journey purpose (employer’s business, commuting, relative to other). This model had an acceptable fit (R-square of 0.69) and several significant coefficients. However, it was found that splitting the explanatory variables and coefficients for these three purposes (thus having three models, one for each journey purpose) gave quite different coefficients, and these differences were statistically very significant, especially for business versus non-business travel. Further segmentation (separate models) within the travel purpose segments did not produce statistically significant results. So, the models we present here were estimated separately for three segments:

- travelling on employer’s business (EB)
- commuting
- other purposes (leisure).

A full list of the explanatory variables can be found in Table 1, whilst the random effects estimation results for EB are in Table 2. For comparison the OLS results are also presented.

It can be seen from Table 2 that there is a large degree of variation in the value of travel time savings. The models are able to explain around 36% (the R square at the bottom of the table) of that variation. The other 64% of the variation will depend on other attributes of the countries and the methods used in the individual studies, for which there are no variables to include in the model. Similarly to the meta-analysis of the passenger VTTS by Wardman (2004) and unlike that of Zamparini and Reggiani (2007b) we obtain a substantial number of significant coefficients. The pattern over time now has relatively high values before 1990 and after 1999, whilst the SP and combined SP-RP studies produce significantly lower VTTS for business trips than resource-based (cost savings) studies. This has also been found for walk and wait time in the UK by Wardman (2004), but here we are studying in-vehicle-times or main-mode travel times. It is also apparent that models on RP data produce lower VTTS for business travel than the cost savings approach (this is further discussed in section 4.3). It should also be noted that the RP, SP and SP-RP studies predominantly rely on interviews with employees only.

With regard to VTTSs, air travel VTTS is higher than those for car and train, whilst the bus VTTS is somewhat lower. These are presumably mostly effects of different user groups for these modes (see the discussion on the effects of mode in section 4.3). It should also be noted that the air dummy is not as important within business travel as it is for commuting and other purposes (see table 3), whilst the train dummy proved to be insignificant.

The strongest influence came from the GDP per capita variable which influences the VTTS positively, with an elasticity value of 0.47. This is one of the most significant variables (see the t-ratios) and also the most important variable in explaining the business VTTS, according to its Beta coefficient[3] (not shown here). We also tested GDP per capita elasticities that differ between time periods (pre 1990, 1990-1994, 1995-1999, post 1999), but the differences between the estimated income coefficients were not significant The GDP per capita elasticity for the last period was 6% higher than for the first period (but not a statistically significant difference). Further discussion on the income elasticity of the value of travel time savings can be found in section 4.3.

The time dummies do not show a linear trend of the VTTS over time, but rather relatively high values (after having corrected for other things such as the GDP increase) before the period 1990 and after 1999. The period 1990-1999 (the base for this variable) was a period of fast growth in GDP per capita for most countries studied and apparently the VTTS did not grow that fast in these years, but rather increased more steadily over time.

Countries outside of Europe have a lower business VTTS, even after controlling for GDP/capita. A number of dummies for various regions of Europe (i.e. East Europe and South Europe) were included in initial model estimations but were found to be insignificant for this travel purpose. The estimate for the country-specific random effect is highly significant. We also observe that the slope coefficients (at the two-digit level) are the same in OLS as in the panel model. The random effects model has worked (see the highly significant term for the variance of the random component), but it shows that

[3] The Beta coefficient or standardised regression coefficient is defined as $\beta.S_x/S_y$, where β is the estimated coefficient and s_x and s_y are the standard deviation of explanatory variable x and dependent variable y.

for this data set the repeated measurements bias only affects the constant and the standard errors.

The estimation results for commuting are presented in Table 3. Those for other purposes (leisure) are in Table 4. From these results it becomes clear that SP and joint SP-RP studies give lower VTTS than studies based on observed outcomes. Again bus transport gets a lower VTTS compared to car and train, and (for leisure) air transport gets a higher VTTS.

Long distance travel has a somewhat higher VTTS, especially for leisure travel. This was also found in the UK and Dutch national VTTS studies (e.g. Gunn et al., 1996) and in Wardman's (2004) meta-analysis on UK sources. Please note that our model only includes a dummy variable for long distance travel as we do not have information from the underlying studies that would allow us to construct a continuous distance variable. The long distance dummy refers to interurban as opposed to urban travel as it is felt that the long distance dummies for commuting and leisure are picking up a different mix of purposes within non-work travel (e.g. more holiday trips and less shopping and commuting trips for longer distances), together with an increasing disutility of long trips (travellers getting tired and/or bored).

The GDP/capita elasticity of the commuting VTTS is 0.67, clearly above that for other purposes (0.52), which in turn is slightly higher than the one for business (0.47). Again income elasticities for different time periods were tested, but these were not significantly different from each other. The GDP per capita elasticity in the final period (post 1999) is only 1% above the one in the first period (pre 1990). For commuting, 30% of the variation in the VTTS is explained by variation in GDP per capita (this comes from a model, not shown here, with GDP as the only regressor variable); for leisure this is only 15%, and for EB it's 14%.

The values of travel time savings from Southern-European studies for commuting and leisure are higher than in Northwest-Europe whereas for business travel the VTTS are practically the same. Please note that the *ceteris paribus* condition applies here: the commuting and other VTTS in Southern-Europe need not be higher than in Northwest-Europe, but when controlling for other effects, including differences in GDP per capita, we get a higher commuting and other VTTS in Southern-Europe. This could be seen as a behavioural difference between nations, or as a correction on the income elasticity. For Eastern-Europe we also find higher values for commuting and other travel. We interpret this as a correction for the impact of GDP per capita, which by itself seems to lead to an 'overcorrection' of VTTS for Southern and Eastern-Europe. This also goes for the non-European countries (commuting, other), but here the business values were lower than for Northwest-Europe.

The time period dummy for the most recent period is significantly positive for leisure travel and indicates an increase in the VTTS after 1999. This could be a sign of an upward trend that needs to be added to the GDP effect when applied to future years.

Finally, the random effects are very significant; nevertheless the slope coefficients are hardly affected when going from OLS to the random effects model.

4.3 Discussion of the results

4.3.1 Income elasticities

One of the most important findings from these regressions is the income elasticities of the VTTS: 0.47 for business, 0.67 for commuting and 0.52 for other purposes. In several countries the VTTS for future years is calculated by using the change of the wage rate over time. However, at least for non-work travel, there is no theoretical justification for assuming proportionality between the VTTS and the wage rate (of GDP per capita). The VTTS is a ratio of the marginal utility of time and the marginal utility of money. The latter is expected to decrease with income, whilst the former might decrease with income as well. Both derivatives are also influenced by many circumstantial factors. The net effect of income increases on the VTTS will probably be positive (dominance of the denominator effect), but this need not be proportional (Hensher and Goodwin, 2004).

Recent empirical evidence also does not support the income proportionality assumption. In the 1985 and the 1994/1995 UK national VTTS survey (Accent and Hague Consulting Group, 1999), a monotonically increasing relationship between income and VTTS was found, but is was not proportional. At the same income levels, the 1994/1995 VTTS were even lower than in 1985, but this is believed to be largely due to the longer distances studied in 1985 (in passenger transport, VTTS clearly increases with distance). Based on the UK 1994/1995 data, income elasticities of the VTTS were calculated from cross-sectional analysis (also taking into account other socio-economic variables and travel conditions). For business travel the average income elasticity was 0.45, for commuting 0.65 and other travel 0.35 (Gunn et al., 1996). Such income elasticities of around 0.5 are also supported by evidence from the transfer of the VTTS in The Netherlands over a ten year (the VTTS studies of 1988 and 1997) period (Gunn, 2000) and the meta-analysis of British VTTSs in Wardman (2004), who found an income elasticity (largely inter temporal) of 0.72. Furthermore, Fosgerau (2004), using semi-parametric methods, obtained an income elasticity of the VTTS of 0.68 on

Danish SP data (when using pre-tax incomes; Fosgerau notes that with after-tax incomes and the relatively progressive Danish taxes the elasticity would be close to 1)[4]. It has been suggested (Gunn, 2001) that the cause for this less than proportional growth of the VTTS with income over time may be the change that has occurred in the disutility of travel time and the productivity of travel time, mainly through the introduction of new technology that can be used whilst travelling (mobile phones, laptop computers, audio and video equipment). In our regression analyses we also find coefficients of around 0.5 for GDP/capita in double-logarithmic models. Price elasticity studies do not show any sign of price elasticity declining over time in a way, which would be expected if VTTS increased with income (Hensher and Goodwin, 2004). The latter authors conclude by warning against using the proportionality assumption; it is overoptimistic on revenue and potentially underestimates the behavioural response.

The income elasticities of the VTTS could be different for comparing countries at one point in time (cross-section elasticity) and for a single country over time (inter temporal or time-series elasticity). The GDP per capita elasticities estimations in this paper are a mixture of both: they are based on values for several countries and for several years. However it can safely be assumed that the cross-sectional variation will be dominating in the estimation results, since that variation in the VTTS between countries in the data set is much larger than within countries. By including dummy-variables for time periods, we have removed some of the time series element from the income elasticities, making them even more like cross-sectional elasticities (please note this didn’t make much difference: the income elasticities are practically the same in

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[4] Fosgerau (2004) also found that in nonparametric regressions without covariates on the Danish SP VTTS survey data the right tail of the VTTS distribution could not be observed and therefore the mean VTTS could not be calculated. This may be interpreted as an indication that present SP designs (and models) are not capturing the highest values of travel time savings, and may underestimate the true income elasticity of the VTTS.

models with and without time period dummies). Consequently, the estimation results from our meta-analysis provide evidence for an income elasticity that might be used for a transfer of VTTS from one country to another for the year 2003 (and more generally a VTTS equation that can be applied for all EU countries to get VTTS for 2003). Whether the estimation results from the meta-analysis can also be used for deciding on how future VTTS can be calculated from present VTTS depends on the agreement with *à priori* expectations (and other literature) on the inter temporal income elasticity of the VTTS. These expectations are different for business and non-work travel.

Goods with an income elasticity between 0 and 1 are called ‘normal goods’ in micro-economics, and ‘luxuries’ if the income elasticity is greater than 1. For commuting and other purposes the relevant theoretical economic models allow for income elasticities (cross-sectional as well as inter temporal) that are smaller than 1. There is more cross-sectional evidence (e.g. several analyses on the national UK VTTS study data of 1994/1995, Gunn (2001); the Swiss national VTTS study of 2003, Axhausen et al., 2003) to support income elasticities below 1.

For business travel there is the theory of the firm that implies an income (or rather marginal productivity of labour) elasticity of the VTTS of 1. Hensher’s approach (Hensher, 1977) extends this theoretical model from the perspective of the employer to include the valuation of the traveller. As a result, the income elasticity can differ from 1. However it is unlikely that this value will be very different from 1, since the contribution of the employer to the total VTTS in Hensher’s formula is substantial (more than half in the 1988 and 1997 national Dutch VTTS surveys).

There is limited empirical evidence on inter temporal VTTS. In this study we found some indications that the intertemporal income elasticity for business travel might be higher than the cross-sectional one, but these results were not statistically significant. Analysis of the changes between the two Dutch national VTTS studies gave an income elasticity (all purposes) of about 0.5. The difference from 1 is explained by technological innovations that can be used while travelling (Gunn, 2001). It is difficult to say whether these constitute a once-and-for-all downward shift of the VTTS or a structural trend that will continue in the future. The income elasticity from the meta-analysis for the UK by Wardman (2004) of 0.72 (all purposes) will also be mostly an inter temporal elasticity (one country studied for 1963-2000).

4.3.2 Effect of type of study

For travelling on employer's business we find in our meta-analysis that SP and combined SP-RP studies produce significantly lower VTTS than resource-based (cost savings) studies. Examples of resource-based values for the value of work time (travelling on employer's business) can be found in Department for Transport (2008) guidance. This has also been found for walk and wait time in the UK by Wardman (2004), but here we are studying in-vehicle-times or main-mode travel times. Of course it is hard to say whether the SP and SP-RP[5] studies or the resource-based studies give the correct VTTS. Willingness to pay (WTP) surveys in which there is an open-ended question about the amount of money one would be willing to pay for some commodity might suffer from strategic biases (respondents stating large amounts of money to

[5] Practically all SP and SP/RP studies in our database did not correct for the panel nature of the data (repeated observations on the same respondents), and this could in principle lead to biased results. Two methods to correct for this are the mixed logit model with individual-specific effects (a method similar to the one we used in the random effects model) and Jackknife or Bootstrap methods (Cirillo et al, 2000). The latter study and subsequent studies using similar methods have provided some evidence that the coefficients values would not be seriously affected by the repeated measurements bias, but their variance estimates would. In the academic literature one now regularly finds applications of the mixed logit model with individual-specific effects to account for repeated measurements on the same individual (especially for SP data).

influence decision-making), but many of the value of travel time savings SP surveys are too complicated for respondents to give a deliberate strategic message. Some authors (e.g. Wardman, 2004) have argued that it's likely that in the SP there is a lack of realism in terms of time constraints and presentation of cost and time values, which could lead to underestimation of the VTTS. This possibility cannot be discarded. However, we now also find that models on RP data produce lower VTTS for business travel than the cost savings approach. We have to consider the possibility that some applications of the cost savings approach, especially 'naïve' costs savings studies that equate the VTTS to the full average wage costs per hour, gives too high a VTTS. This might be due to differences between the average wage rate and the marginal productivity per hour (e.g. due to declining marginal productivity) or to labour market imperfections. Also the naïve method does not take into account that travel time is not necessarily unproductive (e.g. reading a report on the train).

For commuting and other passenger travel, the meta-analysis shows that SP and joint SP-RP studies give lower VTTS than studies based purely on observed outcomes. Again this could be the result of not properly dealing with constraints and the presentation of time and costs in the SP. But the RP material might also be at fault here (e.g. observed mode choice), giving many captive situations instead of time-cost trade-offs. Brownstone and Small (2002) also found for commuters from two different studies on road pricing and express lanes in California (State Route 91 and Interstate 15) that the median SP estimates are lower than (in their case about half of) the median RP estimates. They hypothesise that the difference is at least partly caused by a systematic misperception of travel times: respondents' state perceived travel time savings on the express lanes that are twice the actual time savings

4.3.3 Effect of transport mode

The estimated coefficients for specific modes consist of two effects:

- the users of some mode may have different socio-economic characteristics than the users of another mode (e.g. car users on average have higher incomes than bus users). This is the **user type** effect.
- travelling by some mode may be more productive or less unpleasant than travelling by some other mode (e.g. possibility to read things or use a laptop on a train). This is the **real mode-specific** effect. This could be different between countries or even operators, because the quality of the service offered may differ a lot (e.g. see Polydoropoulou et al, 2004).

Furthermore there could be other attributes of the modes involved in the second type of effect (e.g. one mode could be more reliable than another), and in an SP respondents could be trying to justify their actual choices (justification bias).

In most SP VTTS studies these effects cannot be separated, because car users have been asked to choose between car alternatives and public transport users to choose between public transport alternatives. In four of the international studies included in this meta-analysis, users of some mode were not only asked to trade between choice alternatives for the mode actually used, but also for a mode not actually used for the trip studied:

- The Dutch national VTTS study of 1989 (e.g. reported in Gunn and Rohr, 1996)
- The Swedish national VTTS study (Algers et al. 1996)
- The Norwegian national VTTS study (Ramjerdi et al, 1997)
- The Swiss national VTTS study (Axhausen et al., 2003).

This does not provide enough observations to make the distinction between user type and real mode-specific effects in the meta-analysis, but we can draw on the above mentioned literature to reach some, tentative, conclusions on this.

In the first Dutch national VTTS study (see Gunn and Rohr, 1996), apart from the main study, a number of additional analyses was carried out. One of these concerned the impact of user type versus mode on the value of travel time savings. The main outcomes are in Table 5.

From this table we can calculate that a car driver's value of train time for commuting is 1.327x1.124=1.492 times higher than the car driver's value of car time. The train user's value of car time is 1.142x1.124=1.284 higher than the car driver's value of car time for commuting. Generally speaking train as a mode (first row) has a higher VTTS than car. Also train users in most cases have higher values than car users (second row). User type is less important here than the mode-specific effect. Wardman (2004) remarked that this could change when bus and air users are included. The higher values for the rejected mode (the mode not actually used) point at the presence of a self-selectivity effect.

Another additional SP analysis within the first Dutch national VTTS study looked at urban travel, including bus and tram. For bus and tram users, it was found that the user type effect dominates the mode effect.

In the national Swedish VTTS study (Algers et al, 1996), all respondents except those using long distance trains, were presented with two choice experiments, one with alternatives in terms of the actually chosen mode and one with alternatives referring to an alternative mode. The outcome was that the VTTS for the alternative mode are generally higher than for the mode actually used. This was interpreted as a self-selection effect. The report stated that it was difficult to conclude that there was a real mode-specific effect.

In the Norwegian national VTTS study (Ramjerdi et al., 1997), there were also two within-mode experiments per respondent, one for the chosen mode and one for an alternative mode. For car users, the car VTTS and the public transport in-vehicle VTTS were higher than for travellers who had actually used public transport. This was explained by the fact that car users have on average a higher income than users of other modes (user type effect).

In the Swiss national VTTS study (Axhausen et al, 2003) there were three SP experiments for car drivers:

- Mode choice
- Route choice for car
- Route choice for public transport.

Car route choice for public transport users and destination choice had been discarded after the pre-tests.

In his meta-analysis of the VTTS from UK studies, Wardman (2004) was able to separate the user type and the real mode-specific effect (a large number of his sources consisted of SP experiments for actually used as well as alternative modes). He found that air travellers and combined air and rail travellers have the highest VTTS (after having included a distance effect and journey purpose effects), presumably because the business travellers in these categories are more senior and the leisure travellers have relatively high incomes. Within the other modes, rail users have the highest values (especially in the UK these are travellers with relatively high incomes). Car users have much higher values than bus users (again an income effect). For car users, rail (in-vehicle) and car time are valued similarly, and bus is regarded as somewhat inferior to train and car travel.

Evidence of the real mode-specific effect is also provided in Mackie et al. (2003), who report that the VTTS for rail is smaller than the VTTS for car, which is smaller than the VTTS for bus for persons that actually use the car.

Our tentative conclusion is that when air, train, bus and car are studied, the user type effects are probably stronger than the real mode-specific effects. In the meta-analysis, bus users have the lowest value of travel time savings and air travellers the highest, mainly because of differences between the users of these modes. But for car users, time in the car and on the train has a lower mode-specific cost than time on the bus.

5. Application of the estimated models

One of the reasons for estimating the meta-models is the application of the equations found to 25 EU countries[6] and Switzerland, to obtain VTTS by purpose (the benefit-transfer procedure) and we report the results in Tables 6, 7 and 8. For countries with proper VTTS, this is for comparison between the values from the meta-analysis and the national values. For countries without VTTS or that are lacking the segmentation by travel purpose, the values from the meta-analysis can be used as provisional values whilst waiting for proper national studies.

The application refers to the year 2003. In application, we used the GDP per capita (for 2003) of each country. The dummies for methods, period before 1990 and the variance of the country were set to 0. The dummy for the period 2000-2005 was switched on. The role of these variables is to get the coefficients for the other variables

[6] There were 25 EU countries in the European Union in 2003, which is the year for which we applied the estimation results. In January 2007, two more states (Bulgaria and Romania) joined the EU.

in the model right. Dummies for mode, purpose, country and distance were switched on or off depending on the VTTS sought. This gives the following values for 25 EU countries plus Switzerland for 2003 (see Tables 6, 7 and 8).

A number of sense-checks on the VTTS from the meta-analysis were carried out. The ratios of commuting to business VTTS is around 0.4 for short distance which is in line with our expectations. The ratio of the other VTTS to the commute VTTS on average is 0.84, which also seems plausible. The bus VTTS is slightly lower than the car driver and train VTTS. The VTTS for air transport can be up to 1.5 times the car driver VTTS. As discussed in section 4, these will mostly be the effect of different user types that have not fully been represented by other variables in the model.

The VTTS that we obtain from the meta-model are within the range of values that are used in a number of European countries as official 'national' values, but closer to the high than to the low end. Especially for Eastern-European and Southern European countries the meta-model values exceed national values (when available). When we would use purchasing power parities, the VTTS in Eastern Europe sometimes even exceed the Western-European values. The meta-model indicates that time is even more scarce in these countries than it is in the West, which may have to do with a high degree of labour participation, the length of the working week and the lower penetration of time-saving equipment (internet, dish-washer, washing machine, micro-wave, etc.) in the households in Eastern Europe.

6. Summary and recommendations for further research

In a meta-analysis we have estimated regression equations on almost 1,300 passenger transport values of travel time savings from studies around the world, mostly studies conducted after 1990. We estimated double logarithmic models with ordinary least squares, but also models that account for the fact that we have repeated observations for the same country (random effects panel models). The estimation results lead to the following general conclusions:

- We find a (largely cross-sectional) income elasticity of the VTTS of about 0.5 for business travel, 0.7 for commuting and 0.5 for other passenger transport.
- Long distances lead to higher VTTS for commuting and other purposes. SP and SP-RP studies give somewhat lower passenger VTTS than the cost savings approach.
- We find significant effects for purpose (business, commuting) and mode (especially for air; less so for bus relative to car and train).
- We obtain higher values of travel time savings in Southern and Eastern European countries, all other things (including GDP/capita) being equal.

Furthermore, the estimation results have been applied to 25 EU countries to get VTTS by purpose, either for comparison against existing national values, or as a basis for our recommendations for countries with missing VTTS.

Future research could include a joint estimation of meta-regression models on the dataset of VTTS studies for the UK only (Wardman, 2004), possibly after updating this with recent studies, with the international VTTS dataset used in this paper. Another way of extending the database would be to estimate a joint meta-model on outcomes of VTTS studies and time and costs elasticities from transport modelling studies, using the formula for the relationship between VTTS and elasticities. Also one could try to account for variation in the service quality of the various modes in different countries and its impact on the variation in VTTS, but this would require collecting data on service quality (e.g. on punctuality). Alternatively, if sufficient values would be available, a meta-analysis on the value of reliability of travel times might be carried out.

Appendix

Distribution of values of travel time savings in the passenger transport data base over countries

	Number of Values	Percent
Australia	10	0.8
Austria	48	3.7
Belarus	1	0.1
Belgium	45	3.5
Chile	2	0.2
Denmark	72	5.5
Estonia	21	1.6
Finland	59	4.5
France	78	6.0
Germany	54	4.2
Greece	46	3.5
Hungary	21	1.6
Ireland	50	3.8
Israel	9	0.7
Italy	46	3.5
Japan	4	0.3
Korea	3	0.2
Luxembourg	23	1.8
Moldova	2	0.2
Netherlands	84	6.5
New Zealand	10	0.8
Norway	60	4.6
Portugal	48	3.7
Russia	2	0.2
Spain	46	3.5
Sweden	128	9.9
Switzerland	69	5.3
UK	201	15.5
Ukraine	1	0.1
US	56	4.3
Total	1299	100.0

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Table 1
Definition of explanatory variables

Variable	Definition
Data Type Dummies	
Rpdummy	dummy variable that takes the value of 1 if VTTS from model estimated on revealed preference (RP) data; 0 otherwise (base=cost savings approach).
Sprpdummy	dummy variable that takes the value of 1 if VTTS from model estimated jointly on RP and stated preference (SP) data (base=cost savings approach for EB; base is RP for commute and other); 0 otherwise
Spdummy	dummy variable that takes the value of 1 if VTTS from model estimated on SP data (base=cost savings approach for EB; base=RP for commute and other); 0 otherwise.
Mode Dummies	
Airdum	dummy variable that takes the value of 1 if VTTS for travel by airplane (base=car & train); 0 otherwise
Busdum	dummy variable that takes the value of 1 if VTTS for travel by bus (base=car & train); 0 otherwise.
Economic Variable	
Lngdpcap	natural logarithm of GDP per capita (in 2003 Euros).
Time Dummies	
Pre90	dummy variable that takes the value of 1 if VTTS for a year before 1990 (base=1990-1999); 0 otherwise.
Yr0005	dummy variable that takes the value of 1 if VTTS for a year from 2000 until 2005 (base=1995-1999); 0 otherwise.
Country Dummies	
Non-Europe	dummy variable that takes the value of 1 if VTTS for a country outside Europe (base is Europe); 0 otherwise.
Seurope	dummy variable that takes the value of 1 if VTTS for a country in Southern-Europe (base is Northwest-Europe); 0 otherwise.
Eeurope	dummy variable that takes the value of 1 if VTTS for a country in Eastern-Europe (base is Northwest-Europe); 0 otherwise.
Distance Dummy	
Longdisdum	dummy variable that takes the value of 1 if VTTS for long distance travel (base =short distance); 0 otherwise.
Variance Variable	
Variance Country	the variance of the random effect.

Table 2
OLS & random effects model – employers' business

	OLS Estimates		Random Effects Model	
	coefficient	t-ratio	coefficient	t-ratio
Constant	-1.45	3.29	-1.75	3.19
rpdummy	-0.47	2.82	-0.47	2.85
sprpdummy	-0.22	4.63	-0.22	4.68
spdummy	-0.40	6.55	-0.40	6.63
airdum	0.32	4.71	0.32	4.77
busdum	-0.22	4.25	-0.22	4.30
lngdpcap	0.47	10.45	0.47	10.58
pre90	0.71	4.24	0.71	4.29
yr0005	0.31	2.29	0.31	2.32
non-Europe	-0.33	2.19	-0.33	2.21
variance country	na	na	0.17	14.76
Fit	R Square: 0.36		n = 436	

Table 3
OLS & random effects model – commute

	OLS Estimates		Random Effects Model	
	coefficient	t-ratio	coefficient	t-ratio
Constant	-4.40	4.49	-4.13	5.0
sprpdum	-0.38	4.40	-0.37	4.4
spdum	-0.44	6.28	-0.43	6.3
busdum	-0.19	2.82	-0.19	2.8
longdistance	0.17	1.98	0.17	2.0
lngdpcap	0.68	6.95	0.67	7.0
row	0.32	4.31	0.32	4.3
seurope	0.22	2.89	0.22	2.9
eeurope	0.59	2.85	0.58	2.9
yr0005	-0.03	0.49	-0.03	0.5
variance country	na	na	0.12	12.0
Fit	R Square: 0.55		n = 288	

Table 4
OLS & random effects model – leisure

	OLS Estimates		Random Effects Model	
	coefficient	t-ratio	coefficient	t-ratio
Constant	-3.18	4.50	-2.42	4.3
sprpdum	-0.46	6.39	-0.46	6.4
spdum	-0.29	4.59	-0.28	4.6
airdum	0.34	3.43	0.33	3.4
busdum	-0.35	7.35	-0.35	7.4
longdistance	0.30	5.72	0.30	5.7
lngdpcap	0.53	7.50	0.52	7.5
row	-0.03	0.29	-0.03	0.2
seurope	0.37	6.14	0.36	6.2
eastbloc	0.36	1.91	0.35	1.9
yr0005	0.51	6.31	-0.51	6.3
variance country	na	na	0.20	16.2
Fit	R Square: 0.45		n = 526	

Table 5
Values of travel time savings relative (% difference) to car driver values of car time, 1989 Dutch national VTTS study

	Commuting	Business	Other
Train in-vehicle-time	+32.7	+20.4	+1.7
Train user	+14.2	-2.7	+1.2
Rejected mode (car time valued by train user or train time valued by car user	+12.4	+7.7	+1.0

Table 6
VTTS for 25 EU countries and Switzerland in 2003 (2003 euro per hour): business travel

	Business		
Country	Air	Bus	Other modes (car, train)
Austria	39.30	22.90	28.54
Belgium	38.00	22.15	27.59
Cyprus	29.20	17.01	21.20
Czech Republic	20.24	11.79	14.70
Denmark	43.64	25.43	31.69
Estonia	18.44	10.75	13.39
Finland	39.31	22.91	28.54
France	38.14	22.23	27.70
Germany	38.26	22.29	27.78
Greece	27.64	16.11	20.07
Hungary	18.91	11.02	13.73
Ireland	42.03	24.49	30.52
Italy	35.14	20.48	25.52
Latvia	17.09	9.96	12.41
Lithuania	17.07	9.94	12.39
Luxembourg	53.17	30.98	38.61
Malta	25.22	14.70	18.31
Netherlands	38.34	22.34	27.84
Poland	18.07	10.53	13.12
Portugal	26.28	15.31	19.08
Slovakia	17.35	10.11	12.60
Slovenia	26.41	15.39	19.18
Spain	31.07	18.11	22.56
Sweden	42.07	24.52	30.55
UK	40.45	23.57	29.37
EU Average	*33.05*	*19.26*	*24.00*
Switzerland	45.95	26.78	33.36

Table 7
VTTS for 25 EU countries and Switzerland in 2003 (2003 euro per hour): short distance commute travel

Country	Bus	Other modes (car, train)
Austria	8.52	10.30
Belgium	8.12	9.82
Cyprus	6.95	8.40
Czech Republic	5.91	7.14
Denmark	9.89	11.96
Estonia	5.17	6.26
Finland	8.52	10.30
France	10.17	12.30
Germany	8.20	9.91
Greece	6.43	7.77
Hungary	5.36	6.48
Ireland	9.37	11.33
Italy	9.05	10.94
Latvia	4.64	5.61
Lithuania	4.63	5.60
Luxembourg	13.11	15.85
Malta	5.64	6.82
Netherlands	8.22	9.94
Poland	5.02	6.08
Portugal	5.98	7.23
Slovakia	4.74	5.74
Slovenia	8.63	10.44
Spain	7.59	9.18
Sweden	9.39	11.35
UK	8.87	10.73
EU Average	*8.84*	*10.69*
Switzerland	10.64	12.87

Table 8
VTTS for 25 EU countries and Switzerland in 2003 (2003 euro per hour): other-short distance travel

Other-Short Distance		
Country	Bus	Other modes (car, train)
Austria	5.77	8.18
Belgium	5.55	7.88
Cyprus	5.95	8.44
Czech Republic	3.93	5.57
Denmark	6.47	9.19
Estonia	3.54	5.03
Finland	5.77	8.18
France	7.99	11.34
Germany	5.60	7.94
Greece	5.60	7.94
Hungary	3.64	5.17
Ireland	6.21	8.81
Italy	7.30	10.36
Latvia	3.26	4.62
Lithuania	3.25	4.61
Luxembourg	8.05	11.43
Malta	5.06	7.18
Netherlands	5.61	7.96
Poland	3.46	4.91
Portugal	5.29	7.51
Slovakia	3.31	4.70
Slovenia	5.27	7.48
Spain	6.37	9.04
Sweden	6.22	8.82
UK	5.95	8.45
EU Average	*6.32*	*8.97*
Switzerland	6.85	9.72

Figure 1
Funnel plot for the commuting VTTS against sample size (for studies that reported sample size)