THE TOLL ROAD ALTERNATIVE: VARIATIONS IN CHOICE BEHAVIOUR AND VALUES OF TIME

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INTRODUCTION

The adoption of road user tolls to help finance interconnected or single sections of high quality road infrastructure is common in many countries. The basic motivation is that government investment budgets are too tight, and that users have a willingness to pay for time savings and better driving conditions. When there are alternative routes, the toll rates have to be set right, however, for projects of this kind to be a success.

In the first section of this paper the general situation concerning the use of road tolls in Norway is outlined. Subsequently, a detailed analysis of the behavioural data is given. Descriptive results about variations in toll road usage with background factors are presented, and new evidence concerning the relationships between stated and measured time savings is brought forward.

The last two sections address the question of modelling route choice under the influence of tolls. Simple models for forecasting are described and applied, and more fully specified models based on data from two consecutive years are developed. These are applied to study variations in values of time.

1. CHARGING FOR THE USE OF ROAD SPACE IN NORWAY

In Norway there is a long tradition of financing sections of road infrastructure, especially bridges and tunnels, by combing road user tolls and public funds. Most of the projects have no free of charge competitive routes in terms of distance or travel time. This is because the tolled sections either replace existing ferry crossings, or they establish new links in the road network. In times of steady traffic growth, creating enough revenues to defend the private sector involvement usually went according to plan. Often these types of projects generated trips exceeding the overall growth in traffic, and the charging period could in these instances be shortened.

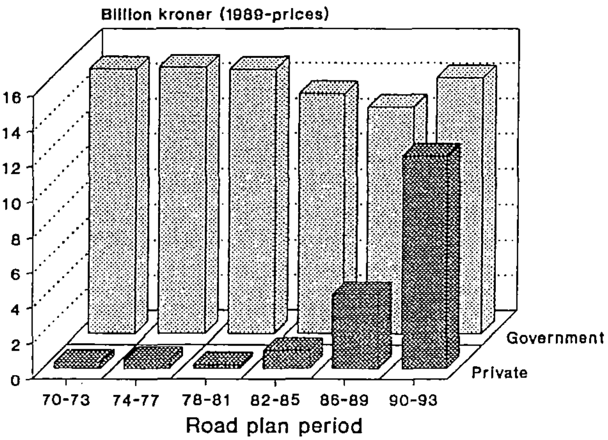
Figure 1 shows the recent trend of increasing private sector share of investments in national (state) highways. For 1991 the contribution from toll companies was expected to be 1.8 billion kroner, which is about one third of the total investments.

One explanation for this large increase in private sector involvement is the introduction of the toll rings in Bergen (January 1986), Oslo (February 1990) and Trondheim (October 1991). The original political agreement was to raise extra private sector money, to be matched by extra government money, to fulfil urban road building programmes in much shorter time than otherwise possible. The contents of the investment packages and the design of the schemes have, however, changed in line with increasing environmental awareness and developments in technology.

While the focus of the original argument for the Bergen toll ring was entirely on road building, the emphasis widened to include infrastructure investments for public transport, cyclists and pedestrians in the Oslo and Trondheim schemes. The Trondheim toll ring is the first scheme to have no monthly or yearly passes that allow an unlimited number of crossings. Tolls are charged per vehicle Mondays through Fridays from 06:00

to 17:00 for all inbound traffic. Charge levels during the morning peak are higher than later in the day, which indicates that the payment scheme is not entirely fiscal. It is also designed to influence car drivers choice mode and departure time.

Figure 1
Private and government investments in national highways



Source: Samferdselsdepartementet,1991

As a result of a liberal credit policy and no government control on the issue of bonds, economically more marginal toll projects have been started. Some have even been financed entirely by borrowing. Others have been built in areas where competitive (old) free of charge routes existed.

The question of traffic diversion from the new route has thus become important. Environmental objectives of the new projects may not be met, and toll companies risk running into financial difficulties. This is exactly the case for the project that we now turn our attention to.

2. THE TOLL ROAD STUDY

On the E6 national highway route east of Trondheim in the direction of the airport, the first tolled section was opened in 1988. The motivation for building a new road was to divert through traffic from the heavily built-up area of the old route for environmental and traffic safety reasons, and to provide a faster connection between the city and the airport.

The toll project has since been in operation 24 hours a day, and drivers passing through the toll plaza located at the periphery of the city have to pay in both directions. The charge was 10 kroner for light vehicles and 25 kroner for heavy vehicles in 1988 and 1989. This was increased to 20 kroner and 40 kroner in 1990, in conjunction with the latest extension of the tolled route. (February 24, 1992 1 USD($) was equivalent to 6.51 kroner, 1 GBP(£) to 11.30 kroner and 100 FRF to 115 kroner.)

2.1. The choice situations

A special feature of the payment scheme is that drivers can deposit money in their personal toll-account, and pass through the toll plaza without any delay, being identified as bona fide account holders by the identity of their personal electronic tag mounted inside the windscreen.

In 1989 a second section was opened, and the toll company could offer motorists 12.5 km of motorway driving conditions. The old route had a much lower standard and passed through built-up areas with several local speed limits of 50, 60 or 70 km/h. Its length was roughly equal to the new route, and it was available free of charge.

During 1990 the new motorway was lengthened by 7.5 km, thereby presenting long-distance traffic with the choice of "buying" larger time savings than in 1989, but at a higher price. The old route was still similar in length to the motorway route for long-distance traffic, and available free of charge.

Choosing the old route in the direction of the city implied the risk of some queuing during the busiest time of the morning peak.

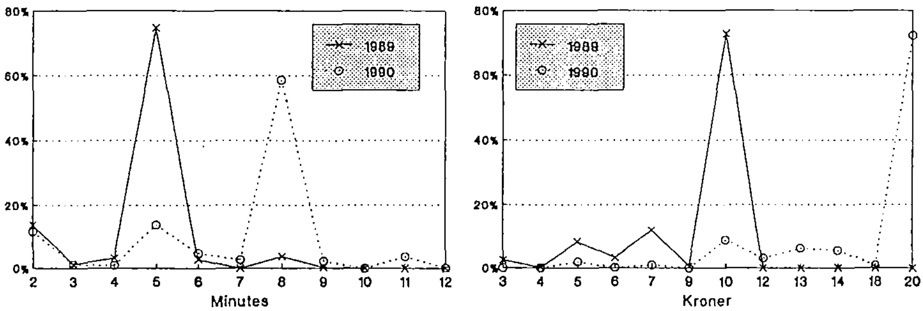
Interview surveys were conducted on users of both routes in November 1989 and November 1990, and average driving times between key origins and destinations were measured. In order to cover most trip purposes during a week, questionnaires relating to the drivers' current trip were handed out at certain time periods during three consecutive days (Sunday, Monday and Tuesday).

Total average daily traffic on the two routes passing the cross-section where the toll plaza is situated were around 18 000 vehicles in both interview periods. Two thirds of the returned forms came from choosers, i.e. time versus money traders, in the sense that the tolled route represented the shortest (measured) time route, given the drivers' own statements about origin and destination.

2.2. Time savings and costs for light vehicles

Time savings depended on the drivers' origin and destination, and on whether it was a trip during the morning peak towards Trondheim or not. A small time delay was imposed on drivers who did not possess a tag, due to time that was, or would have been, spent in money transactions at the toll plaza.

Figure 2
Distribution of actual time savings and costs, rounded to whole numbers



It can be seen from Figure 2 that the number of minutes to be gained by choosing the tolled section was quite modest. For the choosers represented in the samples, average time savings increased from 4.4 minutes in 1989 to 6.8 minutes in 1990. The mode of the distributions increased from 5 to 8 minutes.

The mean costs were 8.85 kroner in 1989 and 17.63 kroner in 1990. Note that the X-axis in Figure 2 is not scaled, only the values which actually occurred are shown. Drivers with no tags had to pay the full price of 10 kroner in 1989 and 20 kroner in 1990. Slightly less than 30 % of drivers in both years possessed a tag. These had variations in their cost per trip depending on how many trips they had prebought. For instance, in 1990 the price per trip was reduced to 18, 16, 14, 12 or 10 kroner if the number of trips bought in advance were 25, 50, 100, 250 or 500 respectively.

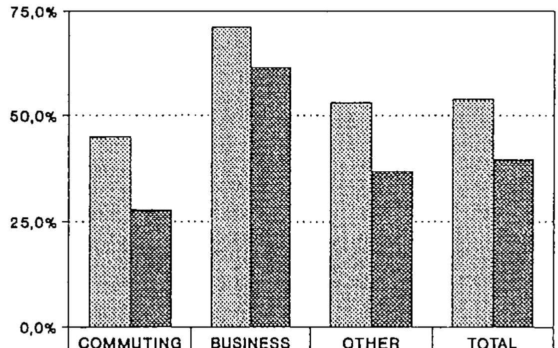
If the driver stated on the questionnaire that others had, or would have, contributed to the payment (e.g. cost sharing with passengers or some kind of company car arrangement), the cost variable was reduced by 50 % for non-business travel purposes. The rationale for doing this was that company car usage for private purposes is taxed in Norway, so the marginal cost of a private trip is never zero. If the toll was paid by the employer and it was a business trip, the actual cost was not reduced, since for this trip purpose it is as much the employer's willingness-to-pay for time savings that is revealed.

It could be suspected that the possession of a tag, and the size of the rebate per trip for tag owners, were related to income. The correlations between the final cost variable and gross personal income were -0.189 in 1989 and -0.214 in 1990. For the subsamples having a tag, the correlations were -0.162 in 1989 and -0.116 in 1990.

2.3. The choices

Figure 3 shows that usage of the tolled section dropped from 54% in 1989 to 40% in 1990. Purpose groups *Commuting* and *Other* reacted more sharply to the price increases than *Business*. In general, drivers' reactions reveal that they did not find the extra time savings worth the double price.

Figure 3
Usage of the tolled section in 1989 and 1990



	COMMUTING	BUSINESS	OTHER	TOTAL
1989	45,0%	71,2%	53,0%	53,8%
1990	27,8%	61,5%	36,8%	39,6%

In Table 1 the distributions of some key background variables are shown, together with the percentage choosing the tolled section for each subgroup. It can be seen that the background variables were very stable. A small shift towards higher income classes can be noticed. Mean annual incomes increased by 3% from 183 00 kroner in 1989 to 189 000 kroner in 1990, which was identical to the inflation rate that year.

Table 1
Summary characteristics of choices in 1989 and 1990

VARIABLE	1989		1990	
	% OF OBSER-VATIONS	% CHOOSING TOLLED SECTION	% OF OBSER-VATIONS	% CHOOSING TOLLED SECTION
GROSS PERSONAL INCOME GROUP (KRONER/YEAR)				
0 - 100 000	16.4	43.4	15.9	23.9
101 - 150 000	19.7	46.3	18.0	34.3
151 - 200 000	33.9	53.7	32.3	37.0
201 - 250 000	15.9	60.8	16.9	45.2
251 - 300 000	7.6	67.4	9.1	53.9
> 300 000	6.5	70.3	7.8	64.4
FREQUENCY OF CHOICE SITUATION				
Daily	56.8	46.1	52.3	30.7
Weekly	18.7	61.6	19.0	43.2
Monthly	14.2	69.1	15.1	51.3
More seldom	10.4	60.1	13.6	54.0
WHO PAYS THE TOLL?				
Car driver alone	70.7	47.2	71.5	29.8
Others, partly or completely	29.3	72.5	28.5	68.3
WAY OF PAYING				
Cash	72.0	44.0	72.1	29.4
Tag	28.0	80.6	27.9	67.4
TRIP LENGTH				
Short/local	67.2	44.8	64.9	30.0
Long	32.8	72.8	35.1	57.5

Commuting had an income increase of about 5%, *Other* 2% and *Business* no increase. Mean incomes were largest for *Business*; 32% above *Commuting* in 1989 and 25% above *Commuting* in 1990. *Other* had mean incomes that were 2% below *Commuting* in 1989 and 5% below *Commuting* in 1990.

The percentages of drivers travelling the sections daily and on short trips were slightly smaller in 1990. The shares of drivers paying cash and paying completely out of their own pockets were very similar. The columns displaying the percentage choosing the tolled section show a very clear pattern. First, in both years there is increased usage with (1) increased income, (2) lower frequency of travelling the sections, (3) others paying, (4) owning a tag and (5) increased length of the journey. Second, in each cell usage is down in 1990 compared to 1989.

It is evident from these results that travel-related factors, as well as details in connection with money transactions, play key roles in determining travellers' choice of route. We return to this point in section 4.

2.4. Subjective versus objective time savings

In both years drivers in general believed that the savings in travel time earned by choosing the tolled section were larger than they were objectively, as measured by observers using the car-following method. We like to make clear that drivers on the old route were asked how many minutes of travel time they thought they would have saved, if they had chosen the tolled route for their current trip. Drivers on the tolled route were asked how many minutes they thought they had saved, by choosing the tolled route for their current trip.

In 1989 the average subjective time saving was 6.7 minutes, compared to the objective value of 4.4 minutes. This changed to 7.6 minutes subjectively in 1990, compared to 6.8 minutes objectively. The overestimation thus improved from +2.3 minutes to only +0.8 minutes; in percentage terms from +57% to +23%. We think that the effect of learning is the main explanation for this improvement.

Some insight into how overestimation of time savings depended on background factors is provided by Table 2, which shows the differences between subjective (stated) and objective (measured) time savings for subgroups.

Table 2
Overestimation of time saving on the tolled section by subgroups in 1989 and 1990

VARIABLE	1989 (minutes)	1990 (minutes)
FREQUENCY OF CHOICE SITUATION		
Daily/weekly	2.1	0.8
Less frequent	2.5	0.8
WHO PAYS THE TOLL?		
Car driver alone	2.8	1.2
Others, partly or completely	2.1	0.7
WAY OF PAYING		
Cash	2.1	0.7
Tag	2.6	1.1
TRIP LENGTH		
Short/local	2.1	0.9
Long	2.4	0.6
PURPOSE GROUP		
Commuting	2.1	0.7
Business	2.6	1.1
Other	2.2	0.8
CHOSEN ALTERNATIVE		
Old section	1.2	0.3
Tolled section	3.1	1.6

Drivers on the tolled section overestimated most seriously in both years, which indicates a sort of selection bias. It is almost surprising that 1990 toll road choosers did not overestimate even more, because of the effect of rationalising their payment of twice the charge from the previous year.

People who travel the routes often, or have their origins or destinations locally are bound to know the attributes of the choice alternatives better, and the results show that their estimates are more accurate. We can also see that drivers who pay the toll completely out of their own pockets, or who have taken the effort of acquiring a tag, are more likely to exaggerate their time savings. This could be taken as evidence of attempts to correct the psychological strain referred to by Festinger (1964) as cognitive dissonance.

One result in Table 2 that cannot be explained easily by intuitive reasoning is that 1990 drivers on long trips overestimated less than drivers on short trips. In fact, the only subgroup that underestimated the time saving slightly was 1990 drivers on long trips who had chosen the old free of charge route.

3. ESTIMATION AND APPLICATION OF SIMPLE 1989 CHOICE MODELS

Fairly simple and easy to apply models are often required for forecasting purposes. In this chapter we will describe how binary logit models containing only cost and time variables estimated on 1989 data performed when applied to predict 1990 choices. The utility functions are:

$$V_{\text{tolled section}} = \text{Constant} + b_1 \times \text{Actual cost} + b_2 \times \text{Time saved (measured or stated)}$$

$$V_{\text{free section}} = 0$$

The constant, b_1 and b_2 will be estimated separately for each purpose group. The probability for choosing the tolled section is given by the logit formula:

$$P(\text{tolled section}) = 1/\{1 + \exp(-V_{\text{tolled section}})\}$$

3.1. Estimation results from 1989 data

Table 3 shows that the cost parameters within each purpose group are relatively unaffected by the inclusion of measured or stated time saving as the other explanatory variable. Commuters have the largest sensitivity to cost, followed by business travellers and travellers with other purposes.

This can be explained by the fact that the tolls make up a larger budget post for commuters, since the trip has to be done twice a day. People on a business trip seldom pay the tolls themselves, and the third group includes a large share of less frequent choosers.

All models using stated time saving show a better fit than the corresponding models using measured time saving. This is reasonable, since people base their decisions on their own subjective impressions of the attributes of alternatives, rather than on the more objective (true) engineering values. Stated time saving parameter values are smaller, since variable values are larger.

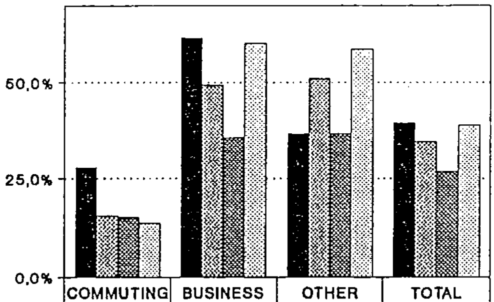
Table 3
1989 estimation results using measured or stated time saving. T-values in brackets

VARIABLES AND KEY STATISTICS	PURPOSE GROUP					
	COMMUTING		BUSINESS		OTHER	
	1a	1b	2a	2b	3a	3b
Constant	2.298 (6.7)	2.694 (9.0)	0.3035 (0.4)	2.327 (4.4)	-1.278 (-2.3)	0.2385 (0.5)
Actual cost on the tolled section	-0.5048 (-16.7)	-0.5239 (-16.9)	-0.3170 (-6.1)	-0.3482 (-6.5)	-0.1733 (-3.6)	-0.1690 (-3.5)
Measured time saving on the tolled section	0.4013 (9.1)		0.7696 (7.3)		0.7123 (10.0)	
Stated time saving on the tolled section		0.2369 (12.3)		0.2617 (9.3)		0.2391 (11.6)
Sample size	1697	1697	911	911	1186	1186
Rho-squared (0)	0.2455	0.2826	0.2409	0.2759	0.0924	0.1153

3.2 Applying the 1989 models for forecasting usage in 1990

Actual shares on the tolled section in 1990 for each purpose group and total are presented in Figure 4, together with the corresponding results from three different prediction runs. All predictions are done by the sample enumeration method, which implies that individual choice probabilities are calculated for every respondent in the 1989 sample. Predicted usage in 1990 is calculated as the unweighed sum of the probabilities of the tolled route. Only information that would have been known in advance of the decision to increase prices are used in the exercises.

Figure 4
Actual and predicted usage 1990



	COMMUTING	BUSINESS	OTHER	TOTAL
Usage 1990	27,8%	61,5%	36,8%	39,6%
Prediction 1	15,6%	49,3%	51,0%	34,7%
Prediction 2	15,2%	35,7%	36,8%	26,9%
Prediction 3	13,7%	60,1%	58,6%	38,9%

In the first prediction, models 1a, 2a and 3a are used, with actual cost increased by 100% and measured time saving increased by 50% for every individual. The second prediction is by models 1b, 2b and 3b, and actual cost is again increased by 100% and stated time saving by 50%. The third prediction is a more realistic application of models 1a, 2a, and 3a, since measured time savings in 1990 according to the origin and destination of each trip maker was used.

It can be seen from Figure 4 that both applications of the models using measured time saving as the explanatory time variable worked very well in total, and especially prediction 3. The applications using stated time saving underestimated total demand seriously.

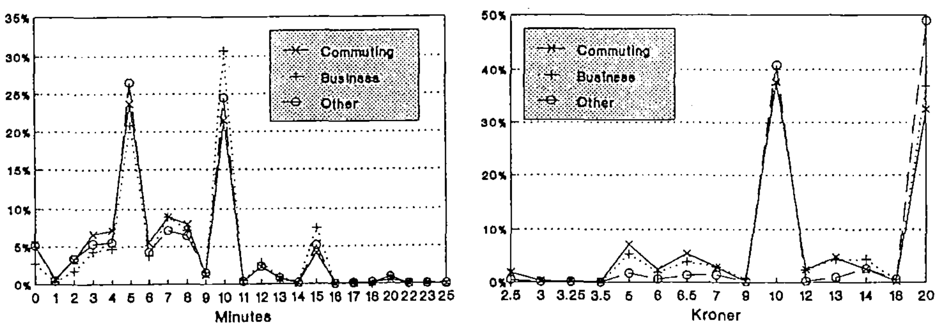
All the predictions consistently underestimated the commuting share. This means that commuters in 1990 were more willing to pay for time savings, than could be inferred from the 1989 data.

One should allow for the possibility that the good performance of predictions 1 and 3 is partly due to chance, considering the significant underestimation of *Commuting* and the overestimation of *Other* trips. It is a risky business to make forecasts using simple models estimated on data from one site and one point in time only. It should be concluded that employing this kind of simple models for planning purposes requires careful validation and judgment.

4. GENERALISATIONS ON THE VALUES OF TIME

In this section the focus is on variations in the car drivers' willingness to pay for marginal time savings, rather than forecasting future demand. The 1989 and 1990 samples are added together, and we use stated rather than measured time saving as the explanatory variable. Figure 5 shows that the range is wider than for measured time (Figure 2). Note that the X-axes are not to scale, since only the occurring values are shown.

Figure 5
Distribution of stated time savings and actual costs, rounded to whole numbers



A rounding effect is noticeable in peoples' estimates of time savings, causing distinct peaks at the values of 5, 10 and 15 minutes. Notice that small minorities (5%) of the *Commuting* and *Other* groups have the impression that there are no time savings associated with the tolled route. Figure 5 also shows that drivers with purpose *Other* have a higher propensity of paying the full charges.

The pooled sample allowed more complete model specifications to be estimated. The questionnaire did not contain variables like sex, household composition, personal occupation or age group. But it was possible to take into account the effects of the length of the trip, whether the driver was a frequent traveller in the area, and whether he or she covered the cost privately or not. The effects of income were modelled by segmentation into six gross personal income groups.

Table 4 shows the results for the whole sample and for each purpose group. It should be noted that all parameters are attached to the utility function of the tolled alternative. The utility is specified in such a way that all parameters having names like "+ Cost if ..." are additive corrections to the base actual cost parameter. This way of specifying the effects of income group on the cost variable is adopted from the Dutch Value of Time Study (HCG, 1991).

Table 4
Pooled estimation results. T-values in brackets

VARIABLES AND KEY STATISTICS	WHOLE SAMPLE	PURPOSE GROUP 1c COMMUTING	2c BUSINESS	3c OTHER
Constant	0.4071 (4.6)	0.4870 (3.4)	0.8105 (4.4)	0.1863 (1.3)
Actual cost on the tolled section (base)	-0.2488 (-31.7)	-0.2744 (-21.6)	-0.2452 (-15.5)	-0.2259 (-14.7)
Stated time saving on the tolled section	0.2355 (27.4)	0.2408 (17.4)	0.2424 (13.5)	0.2226 (15.7)
+ Cost if income ≤ 100 000	-0.03432 (-5.7)	-0.02971 (-2.6)	-0.00886 (-0.6)	-0.03146 (-3.7)
+ Cost if income 101 - 150 000	-0.00424 (-0.7)	-0.00177 (-0.2)	0.01167 (1.0)	-0.00866 (-1.0)
+ Cost if income 201 - 250 000	0.01039 (1.7)	0.02355 (2.0)	0.00222 (0.2)	0.00507 (0.5)
+ Cost if income 251 - 300 000	0.03758 (5.0)	0.05795 (4.2)	0.02291 (1.8)	0.03472 (2.8)
+ Cost if income > 300 000	0.03954 (4.8)	0.05921 (3.4)	0.04310 (3.4)	0.01284 (0.9)
+ Cost if on a long distance trip	0.05882 (14.4)	0.06782 (8.3)	0.03688 (4.8)	0.06475 (10.7)
+ Cost if infrequent traveller in the area	0.07129 (16.2)	0.07347 (7.4)	0.05708 (6.7)	0.06825 (6.5)
+ Cost if others contribute to toll payment	0.06420 (13.7)	0.01117 (0.8)	0.06390 (8.0)	0.03959 (3.8)
Sample size	8197	3464	2051	2682
Final likelihood	-4073.6	-1575.2	-997.3	-1453.6
Rho-squared (0)	0.2830	0.3440	0.2985	0.2181

The large purpose group differences between the base *Actual cost* parameters and between the *Stated time saving* parameters noted in Table 3 have disappeared. Differences in preferences between purpose groups are mainly accounted for by the additive cost parameters. A test statistic for the null hypothesis (H_0) of no taste variations across the purpose group segments, can be computed as twice the difference in final likelihoods between the whole sample and the sum of likelihoods for the segments (Ben-Akiva and Lerman, 1985). It is χ^2-distributed with, in this case, 3×11-11=22 degrees of freedom. χ_{test} works out at 95.0, compared to $\chi_{22,.01}$=40.3, so H_0 can be firmly rejected at the 1% level.

In Table 5 implied values of time resulting from the estimations are shown. Values for each income segment are calculated, with additive and independent percentage adjustments for the effect of other factors.

Table 5
Willingness to pay (kroner/hour) per vehicle for time savings according to models 1c, 2c and 3c. Percentage of observations in brackets

	COMMUTING		BUSINESS		OTHER	
Base values by gross personal income group (kroner/year):						
0 - 100 000	47.51	(18.5%)	57.25*	(6.7%)	51.90	(22.4%)
101 - 150 000	52.32*	(18.5%)	62.28*	(13.2%)	56.94*	(21.8%)
151 - 200 000 (base)	52.65	(33.9%)	59.31	(32.6%)	59.12	(29.8%)
201 - 250 000	57.60	(15.2%)	59.85*	(21.6%)	60.48*	(14.3%)
251 - 300 000	66.75	(8.2%)	65.43	(11.5%)	69.85	(7.2%)
> 300 000	67.14	(5.6%)	71.96	(14.4%)	62.69*	(4.6%)
Adjustments for other factors:						
Trip length						
Short/local (base)	...	(76.9%)	...	(57.4%)	...	(59.8%)
Medium/long	+32.8%	(23.1%)	+17.7%	(42.6%)	+40.2%	(40.2%)
Frequency of choice situation						
Daily/weekly (base)	...	(88.1%)	...	(40.1%)	...	(18.1%)
Less frequent	+36.6%	(11.9%)	+30.4%	(59.9%)	+43.3%	(81.9%)
Who pays the toll?						
Car driver alone (base)	...	(87.4%)	...	(31.9%)	...	(89.2%)
Others, partly or completely	+4.2%*	(12.6%)	+35.3%	(68.1%)	+21.3%	(10.8%)
Average value across the sample per vehicle	72.90		138.33		120.48	
Average value across the sample per person in the vehicle	51.70		89.25		53.31	

* Estimate not significantly different from base group (|t| < 1.8)

The values in the top section of Table 5 apply for travellers that are on a short trip <u>and</u> travel in the area often <u>and</u> pay the toll themselves. These conditions are satisfied by 62% of the commuters, but only by 11% of the drivers on business trips and by 13% of the drivers with other purposes.

At the bottom of Table 5 average computed values across each sample are given, both per vehicle and per person in the vehicle. The adjustments for other factors than income cause the average values of time per vehicle for *Business* and *Other* to be considerably higher than for *Commuting*. Since the *Other* group in general has more passengers per vehicle, average values per person are slightly above 50 kroner for *Commuting* and *Other*, and around 90 kroner for *Business*.

The average value of time for commuters found here is about 40% higher than the corresponding value resulting from mode choice models for the work trip based on a national urban sample (Tretvik, 1989). The national recommended values per vehicle for use in cost-benefit analyses (TØI, 1989) are also smaller for *Commuting* trips (46 kroner), higher for *Business* trips (162 kroner), and considerably smaller for *Other* trips (38 kroner). It should be noted that the recommended values are not based on modern behavioural studies. They are in Norway, as in most other countries, given as standard percentages of the average wage rate in industry. The base values per person in the vehicle in 1989 were 35% for *Commuting*, 134% for *Business* and 20% for *Other*.

The data that was available for this study made it possible to establish that systematic variations existed in car drivers' willingness to pay for small time savings, with purpose group, income and some key characteristics of the journey. It has by no means been a comprehensive enough value of time study. Serious discussions have started however in Norway, and between the Nordic countries, in preparation of the design of national value of time studies.

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