Intelligent Economic Speed Adaptation

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Conference paper
Session XXX

Moving through nets:
The physical and social dimensions of travel
10th International Conference on Travel Behaviour Research
Lucerne, 10-15. August 2003

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Abstract

Internalisation of external costs of transport has hitherto been focused on distance-based charges. While this may affect driven distance, it has no influence on driving behaviour. We demonstrate in this economic field experiment that it today is possible to observe drivers actual behaviour with GPS technology and thus possible to refine the economic incentives. To ensure participation, we give drivers a monthly bonus, which is reduced according to the speed behaviour. We make the experiment with two different bonus levels and two different price levels. Our pricing scheme significantly reduces the proportion speed violations of the participants and we conclude that this is a possible way to improve car drivers speed behaviour

Keywords

Speed violations, Economic incentives, Voluntary road pricing, Economic experiments, International Conference on Travel Behaviour Research, IATBR

Preferred citation

Hultkrantz, Lars, Gunnar Lindberg (2003) **Intelligent Economic Speed Adaptation**, paper presented at the 10th International Conference on Travel Behaviour Research, Lucerne, August 2003.

1. Introduction

Internalisation of external cost of transport has been at the top of the transport policy agenda for a long time. Hitherto, the internalisation debate has focused on (rough) internalisation by driven distance. To handle the externality in speed choice, most societies instead relies on a combination of regulations (speed limits), enforcements (fines) and insurance schemes (deductions and bonus/malus). A common problem for all these instruments is the limited possibility to observe actual behaviour.

However, the development of new technologies, as the Global Positioning System (GPS) and mobile telephone communications together with an improved information infrastructure (digital maps) makes observation of actual behaviour possible today. This will have an impact in the future on both the current regulation and enforcement as well as the practice of insurance companies. Indeed, some insurance companies have started to explore this possibility with 'usage-based insurance rating system'[1].

In this project, *Intelligent economic speed adaptation*, the attention is centred on the need and possibility to refine the economic incentives to not only influence driven distance, but also to shape the behaviour while driving. Drivers that commit less speed violations reduces the accident risk for themselves and also for other drivers - a reduction in speed violations generate a positive externality. Society could influence the production of safety through a subsidy to safe drivers. This possibility was mentioned by Boyer and Dionne (1983, 1987) but never explored because *'it is usually either very difficult or extremely costly to observe self-protecting activities of a particular individual'*. Today this is possible at a reasonable cost.

[1] Progressive, in USA, has tried with a system called Autograph, which bases the insurance rates on how much, when and where the vehicle is driven' (www.progressive.com).

2. Voluntary Road Pricing

In this paper, we report on a vehicle-fleet experiment that evaluates an economic incentive scheme for affecting car drivers´ speed-choice behaviour based on voluntary participation. Unlike traditional programs such as congestion charges or speeding penalties, this bonus scheme involves a combination of subsidies and charges. Although the car driver is charged when exceeding speed limits, she is always better off by joining the program.

In many instances, economic incentives in the form of sticks (charges/fines) are preferred to carrots (subsidies). An ethical argument for charges can be founded on the Polluter Pays Principle. In the transport context this principle can be applied to for instance the car user collective as a whole, in contrast to "victims" of car traffic such as walkers or bikers. However, this argument is not so clear cut as many transport related externalities, such as congestion and air pollution, often are reciprocal, giving detrimental effects within the same user category, thus making for instance the individual car driver a victim as well.

A more substantial motive for choosing charges instead of subsidies is that a program based on charges can be expected to be more effective and efficient than a compensation program (Baumol and Oates, 1988, Ch. 14). Whilst a charge and a subsidy may be equivalent as means for promoting technical substitution of a firm toward cleaner technologies there is a significant difference when it come to the effects on substitution of consumption. Charges induce further reduction of pollution by reducing consumption of "dirty goods", while subsidies may give rise to substitution in the opposite direction. In the road pricing context, as observed by Hau (1994), even if a usage-based compensation scheme would affect motorists driving behaviour in a desired direction, it would also induce them to drive more. This argument in favour of charges can be further strengthened by the observation that subsidies have to be financed, and therefore are burdened by the marginal cost of public funds, while public revenues from road-user charges, on the contrary, can be used to reduce other taxes.

However, we submit that subsidies, and voluntary enrollment, may be very useful means for influencing car driving behaviour. At closer examination, the case against subsidies as part of an incentive scheme is less clear, and the case for mandatory programs not so strong as it has appeared.

First, car driving is subject to multiple taxes and charges. These include petrol taxes, vehicle taxes, and insurance premiums. Therefore, the net effect on car use of a subsidy hinges on whether it is financed by an increase of taxes or charges that also affect car use. A voluntary

program that, when seen in isolation, gives a subsidy, can thus in a broader context be a way of differentiating a general tax or charge for the use of vehicles or roads. For instance, a mandatory traffic liability insurance can be combined with a "voluntary" program that awards good driving behaviour by reducing the insurance premium. Although a subsidy is given to anyone who complies to the program, the insurance as a whole is not subsidizing car use. Another example would be a city with a cordon-based road toll that offers motorists an option to be charged in a more differentiated way according to the actual position of the car and the time of the driving. Such an option would only attract car users that benefit from it, so it has to involve a differential "subsidy" to the regular toll. However, in evaluating the net effect of the program on car use one would have to consider whether the net subsidy was funded by an increase of the level of the cordon toll.

Second, intelligent transport system (ITS) devices for improving the functioning of the traffic system often involves electronic equipment for mobile communication and data processing that is installed in the cars. This aggravates the asymmetric information moral-hazard aspects of traffic control. If the car driver is not provided economic incentives for installing and using such equipment, difficult enforcement problems may arise.

Third, expanding on the observation that a volunatary program can be part of a tax differentiation, the incentives for self selection may be designed so as to reduce the total cost of an ITS program. If the required equipment that is needed in the car is expensive, one would like to give priority to installment in cars used by drivers that really will change their driving behaviour when they get this device. This can, in principle, be achieved by combining a subsidy to installment with charges for non-compliance to the recommendations of the ITS system.

Fourth, in some applications, the countervailing effects of a subsidy on pollution/congestion/safety from increased consumption may be desirable. This can be the case, for instance, if substitution from car to public transit evoked by a congestion charge would increase congestion in the public mode, see Armelius (2003).

Finally, as is well known in the organization literature, real humans´ responses to carrots and sticks may differ from the reactions of the *economic man*. Recent research in experimental economics on so called reciprocal behaviour has shown that many individuals choose strategies in social interaction that are based on "similar responses", i.e. by rewarding friendly acts and punishing hostile behaviour. Therefore, it could be conjectured that car drivers that were awarded for "good driving" would feel a stronger responsibility for compliance to the rules of the program than car drivers that were imposed fines punishing "bad driving".

The economic incentive scheme that is investigated in this study consists of a participation bonus and a (non-linear) charge for speed violations. Although introduced here as a separate program, it could also have been launched as part of for instance a traffic insurance or a vehicle taxation scheme. To simplify the experiment, the subsidy is provided in the form of a fixed montly payment, but in a real application it would probably be preferable to have a usage-related bonus (i.e. related to driving time or driving distance).

3. The Field Experiment

Around 250 private cars and 150 commercial vehicles in the Swedish town Borlänge have in a previous project been equipped with a small computer with digital maps, Global position system (GPS) and mobile communication facilities (Vägverket (2002)). A display in the vehicle informed the drivers about the speed limit and an acoustic signal alerted the driver if they drove faster than the speed limit.

In May 2002, the 114 remaining private carowners that still had the equipment installed were invited to participate in an economic experiment for two month (September and October 2002). They were informed that they would receive a monthly initial bonus with a reduction for each minute they drove faster than the speed limit. The reduction would be between 0 and 2 SEK/minute. They would be randomly assigned to a high or low initial bonus group (250 SEK/month or 500 SEK/month) and the experiment was designed so everyone would at least have a payment of 75 SEK each month.

A majority of the car owners (95 persons out of 114) accepted to participate in the experiment, 9 drivers rejected, and 10 drivers did not respond. Drivers that accepted were divided into six groups, with equal previous speeding behaviour based on preliminary data for September 2001; two high bonus groups with low (1) and high price (2), two low bonus groups with low (3) and high price (4) and two control groups with low (6) respectively high (5) bonus.

The accident risk increases progressively with the speed of the car (Nilsson (2000)). The reduction in bonus was therefore designed in a progressive way, with a level align to the external cost of speed choice. The price for the low price groups was 0.10 SEK/minute for actual speeds 0-10% above the speed limit, 0.25 SEK/minute for speeds 11-20% above speed limits and 1.00 SEK/minute for speed offences above 20%. The group with a high price had to pay the double price.

Data was collected from each car through the mobile communication system once a month. The basic record contained information on X- and Y-coordinates, time and date. The information was recorded between every second and every tenth second as long as the engine was running. The data is summarised in individual speed profiles for each road type (defined as roads with different speed limits). Figure 2 presents the speed profile for roads with speed limit 50 km/h, September 2001 and September 2002 for one participant (car number 58). The participant is member of group 4. The technology was not perfect and a number of filters were

introduced to protect drivers from erroneous charging. At the end of each period, the participants received information about their speed behaviour, the sum of charges and remaining bonus.

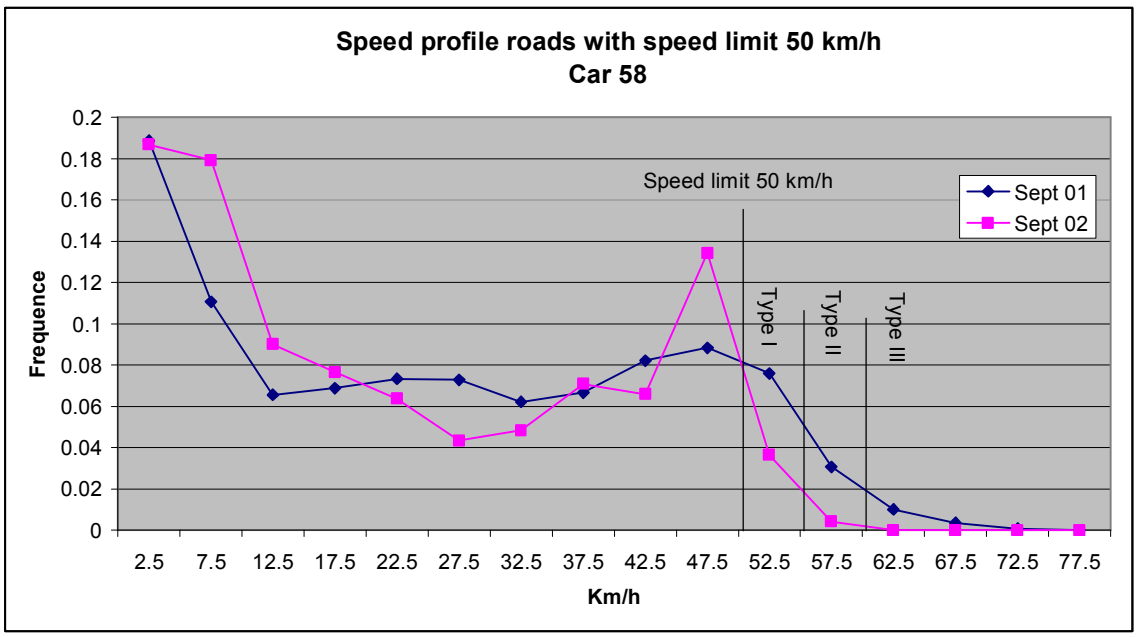
Figure 1 Information to owner of car number 58, September 2002

Speed violations (minutes) and speedcharges (SEK)

Speed violations	Speed limit					Price/minute	Deductio
	30 km/h	50 km/h	70 km/h	90 km/h	110 km/h		Sum
0% to 10% above speed limit	0	3	0	0	0	0,20 kr	,60 kr
11% to 20% above speed limit	0	0	0	0	0	1,00 kr	,00 kr
Above 21% above speed limit	0	0	0	0	0	2,00 kr	,00 kr
Total	0 min	3 min	0 min	0 min	0 min		,60 kr

Fixed monthly payment for the period: *250 SEK*
Deduction speedcharges (rounded): *-1 SEK*
Payment (net before tax): *249 SEK*
This payment will be transferred to Your bank account.
In addition, VTI has paid preliminary income tax directly to the Taxauthority on Your account with: *107 SEK*

Figure 2 Speed profile of car #58 on roads with speed limit 50 km/h September 2001 and September 2002 (with charges)



Speed violations are divided into three types; Type I (0-10%), Type II (11-20%) and Type III (≥ 21%) and presented as driving time (minutes) within each interval (VIOL, VIOL I, VIOL II and VIOL III). A relative measure of speed violation (PVM – proportion violation minutes) is applied for each individual (j) related to the total travel time during the month (M) and expressed for each violation type (i).

$$PVM_{ji} = \frac{VIOL_{ji}}{M_j} \tag{1}$$

i = Type I, Type II or Type III
j= individual 1…114.

PVM will vary greatly between individuals due to individual characteristics we do not observe. Therefore, we utilize the individual difference in behaviour in a *paired-difference test*. We present the *absolute adaptation* as the difference between PVM prior to the experiment and PVM during the experiment for each violation type. Equation 2 below displays the absolute adaptation for an individual when the behaviour in September is compared to the same month previous year.

$$DSSPVM_{ji} = PVM_{ji}^{S2002} - PVM_{ji}^{S2001} \tag{2}$$

Finally, *relative adaptation* for a group of users (J) is expressed for each violation type (i) as equation 3, which is the adaptation between September 2002 and September 2001. For each measure of PVM we only use observations where we have information for both periods.

$$SSPVM_{Ji} = \frac{\frac{\sum_{j=1}^{J} PVM_{ji}^{S2002}}{J}}{\frac{\sum_{j=1}^{J} PVM_{ji}^{S2001}}{J}} - 1 \tag{3}$$

3.1 Participation

The average participant was 57 year old, drove the car 84% of the driving time, had a labour income of 374.000 SEK p.a., a capital income of 21.000 SEK p.a. and a 7.8 year old car. They drove between 428 km and 725 km per month (where we accepted the observations). The distance is short but can be explained by the fact that the equipment was only working inside the

municipal area of Borlänge. The drivers that rejected or did not respond was 5 year younger and had a higher family capital income than participants (difference significant on 90% level).

Non-participants made more speed violations for all month except for May 2002 but none of the aggregate differences (VIOL) were significant. However, non-participants made significantly more severe speed violations (VIOL II and VIOL III) in September 2001. Non-participants always committed a higher proportion speed violations (PVM) and the difference is significant for the more sever violations during the autumn (PVM II or PVM III).

We conclude that we have a self-selection bias in the participation of our experiment. Older drivers that commit less severe speed violations tend to be overrepresented. This compared to non-participants, which nevertheless belong to a very special subgroup of car drivers, i.e. drivers that voluntary has equipped their car with the onboard unit.

3.1.1 Adaptation of participants compared to non-participants

To measure the adaptation we restrict the dataset to individuals where we have observation on behaviour before and during the experiment. As we may compare both with respectively month 2001 or May 2002, we have two measures of adaptation. In general, we would prefer the measure that compares with the same month the year before but as the digital map was improved in May 2002 we also present the latter measure as it sometimes are based on more observations. However, both measures describe the same effects.

After the experiment started, a significant change in behaviour can be observed. The participants now always had significant lower proportion violations (PVM) than the non-participants. Before the experiment, participants drove faster than the speed limit around 14% of their driving time. Corresponding proportion for non-participants were between 16% and 19%. During the experiment, non-participants still drove faster 17% of the time, while the participants had reduced the speed violations to between 7% and 8%. The difference in absolute adaptation between participants and non-participants is significant for all violation types except for the severest violations in October.

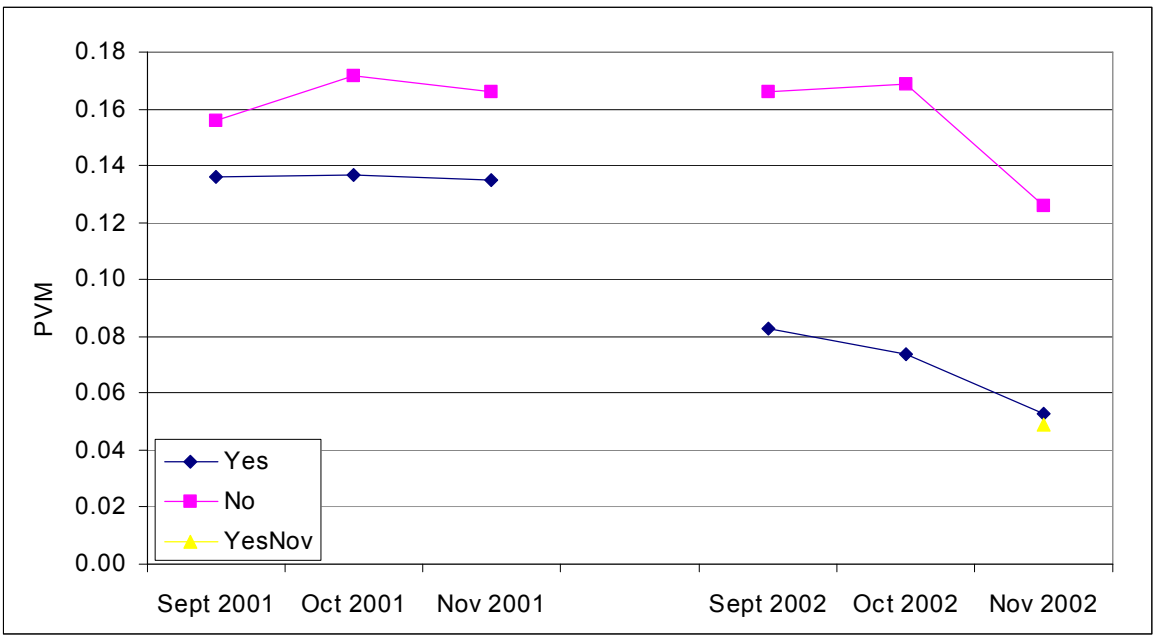
Table 1 Absolute adaptation between each experiment month and the same month 2001

GROUP	Yes			No			Difference		
	Mean	Std dev	Obs	Mean	Stddev	Obs	Mean	Std dev	t-value
September – September									
DSSPVM	-0.05	0.07	72	0.01	0.04	10	0.06	0.07	2.712**
DSSPVM I	-0.03	0.06	72	0.01	0.04	10	0.04	0.06	2.111**
DSSPVM II	-0.01	0.02	72	0.00	0.01	10	0.01	0.02	2.230**
DSSPVM III	-0.01	0.01	72	0.00	0.01	10	0.01	0.01	2.816**
October - October									
DOOPVM	-0.06	0.06	44	0.00	0.04	6	0.06	0.06	2.448**
DOOPVM I	-0.04	0.04	44	-0.01	0.02	6	0.03	0.04	2.098**
DOOPVM II	-0.01	0.02	44	0.00	0.01	6	0.02	0.02	2.246**
DOOPVM III	-0.01	0.02	44	0.00	0.02	6	0.01	0.02	1.324

*) Significant on 90% level, **) Significant on 95% level.

Figure 2 below, depicts the trend in PVM from September 2001 to November 2002 for participants and non-participants. Obviously, the participation in the experiment reduced significantly the proportion speed violations. For the month November, we also have included information on the sub-group of participants that agreed to continue during November (YesNov, see section 3.3).

Figure 3 PVM, all violations, for original participants (Yes) and non-participants (No).

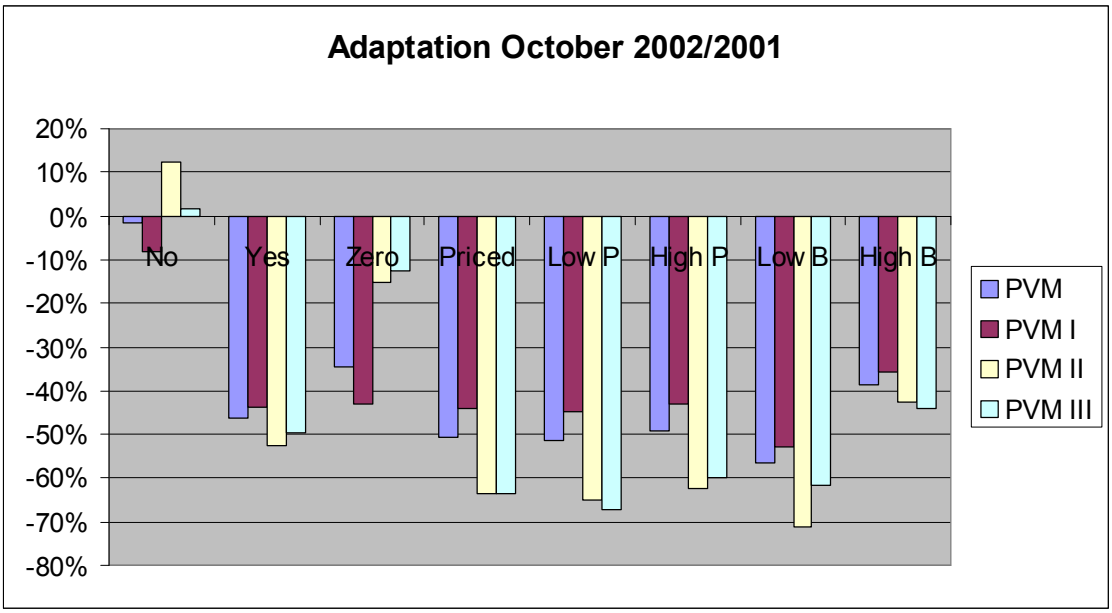


3.2 Adaptation of participants

Within the group of participants we observed a number of significant differences in behaviour which could be attributed to our economic experiment. The figure below depicts an overview over the observations, which are presented in the remaining part of this section.

Four of the experiment groups (64 drivers) had the speed related reduction (high or low price) and two groups (31 drivers) had no reduction (zero-price). Both the priced and non-priced group reduced their proportion speed violation (PVM) in the experiment months compared to the same months previous year. The priced group violated the speed limit 15% of their driving time prior to the experiment and between 7% and 9% during the experiment. The zero-priced group had a violation of 11% and 12% prior and between 7% and 8% during the experiment.

Figure 4 Relative adaptation October 2002 compared with October 2001



The reduction is higher for the priced group compared to the zero-priced group but only few differences are significant (Table X). Three observations can be made; *first*, it is only the difference in adaptation for the more severe violations (PVM 2 and PVM 3) that are significant. As we expect, we find the strongest reaction in the more severe violations with the highest price per minute. While this is a price effect is also reflects that type I violation suffers from the fact that reductions in type II and III may increase type I violations. *Secondly*, the difference in adaptation is more obvious in the second month. This can probably be explained by a learning effect. During the first month of the experiment, numerous drivers contacted the project secretariat and asked if the zero prices really were right. We can assume that after the feedback of the first month they believed that a zero-price was accurate and behaved accordingly. *Thirdly*, the absolute reduction is higher if we compare with May 2002 instead of the same month previous year. This was expected due to the general lower speed in the autumn.

Table 2 Absolute Adaptation, priced and zero-priced participants.

GROUP	Priced			Zero priced			Difference		
	Mean	Std dev	Obs	Mean	Stddev	Obs	Mean	Std dev	t-value
September – September									
DSSPVM	-0.06	0.08	49	-0.04	0.06	23	0.02	0.07	0.851
DSSPVM I	-0.04	0.06	49	-0.03	0.04	23	0.01	0.06	0.687
DSSPVM II	-0.01	0.02	49	-0.01	0.02	23	0.00	0.02	0.905
DSSPVM III	-0.01	0.01	49	-0.01	0.01	23	0.00	0.01	0.537
October - October									
DOOPVM	-0.07	0.05	30	-0.04	0.06	14	0.03	0.06	1.816*
DOOPVM I	-0.04	0.04	30	-0.04	0.03	14	0.01	0.04	0.592
DOOPVM II	-0.02	0.02	30	0.00	0.02	14	0.02	0.02	2.681**
DOOPVM III	-0.01	0.02	30	0.00	0.02	14	0.01	0.02	1.991*

*) Significant on 90% level, **) Significant on 95% level.

3.2.1 Price and Bonus level

A closer examination of the priced group reveals a significant difference in absolute adaptation between low and high-priced users if we compare with May 2002. Compared to the same month the previous year the difference is not significant. The low priced group has a higher average age (8.6 years) and average family age than the high price group but no other difference in socio-economic variables are significant.

Below, the absolute adaptation is presented for low- and high-priced participants by bonus level in a comparison with May 2002. The disaggregation reveals that the difference between low and high-priced drivers is less significant for the high-bonus group.

Table 3 Absolute Adaptation, low and high-priced group by bonus level

GROUP	Low price			High price			Difference		
	Mean	Std dev	Obs	Mean	Stddev	Obs	Mean	Std dev	t-value
September – May	**Low bonus**								
DSMPVM	-0.04	0.05	12	-0.08	0.05	14	-0.04	0.05	-2.072**
DSMPVM I	-0.02	0.04	12	-0.04	0.03	14	-0.02	0.03	-1.469
DSMPVM II	-0.01	0.02	12	-0.03	0.02	14	-0.01	0.02	-1.764*
DSMPVM III	0.00	0.01	12	-0.02	0.02	14	-0.01	0.01	-2.456**
October – May									
DOMPVM	-0.04	0.04	9	-0.12	0.07	10	-0.08	0.06	-2.826**
DOMPVM I	-0.03	0.02	9	-0.07	0.05	10	-0.04	0.04	-2.254**
DOMPVM II	-0.01	0.01	9	-0.03	0.02	10	-0.02	0.02	-2.564*’
DOMPVM III	0.00	0.01	9	-0.02	0.01	10	-0.02	0.01	-3.099**
September – May	**High Bonus**								
DSMPVM	-0.05	0.05	10	-0.10	0.07	12	-0.05	0.06	-1.796*
DSMPVM I	-0.03	0.04	10	-0.05	0.04	12	-0.02	0.04	-1.149
DSMPVM II	-0.01	0.01	10	-0.03	0.03	12	-0.02	0.03	-2.204**
DSMPVM III	-0.01	0.01	10	-0.01	0.01	12	-0.01	0.01	-1.005
October - May									
DOMPVM	-0.06	0.04	10	-0.09	0.07	10	-0.03	0.05	-1.306
DOMPVM I	-0.04	0.02	10	-0.05	0.05	10	-0.01	0.04	-0.825
DOMPVM II	-0.02	0.01	10	-0.03	0.02	10	-0.01	0.02	-1.554
DOMPVM III	-0.01	0.01	10	-0.02	0.02	10	-0.01	0.02	-0.838

*) Significant on 90% level, **) Significant on 95% level.

All participants received a bonus each month, 47 drivers received the low bonus (250 SEK) and 48 drivers the high bonus (48). It is no significant difference between the socio-economic variables between the low and high-bonus groups. During the first experiment month, September, we cannot observe any difference in adaptation between the participants with low bonus compared to the group with high bonus. However, during the second month, we notice a stronger adaptation for the low bonus group but the difference is only significant at 80%-level.

Table 4 Absolute Adaptation, low and high-bonus group

GROUP	Low bonus			High bonus			Difference		
	Mean	Std dev	Obs	Mean	Stddev	Obs	Mean	Std dev	t-value
September - May									
DSMPVM	-0.06	0.05	34	-0.07	0.07	35	-0.01	0.06	-0.361
DSMPVM I	-0.03	0.03	34	-0.04	0.04	35	0.00	0.04	-0.110
DSMPVM II	-0.02	0.02	34	-0.02	0.03	35	0.00	0.02	-0.317
DSMPVM III	-0.01	0.01	34	-0.01	0.02	35	0.00	0.02	-0.606
October - May									
DOMPVM	-0.08	0.06	28	-0.07	0.07	32	0.01	0.07	0.708
DOMPVM I	-0.05	0.04	28	-0.04	0.04	32	0.01	0.04	1.482
DOMPVM II	-0.02	0.02	28	-0.02	0.02	32	0.00	0.02	0.149
DOMPVM III	-0.01	0.01	28	-0.01	0.03	32	0.00	0.02	-0.447

*) Significant on 90% level, **) Significant on 95% level.

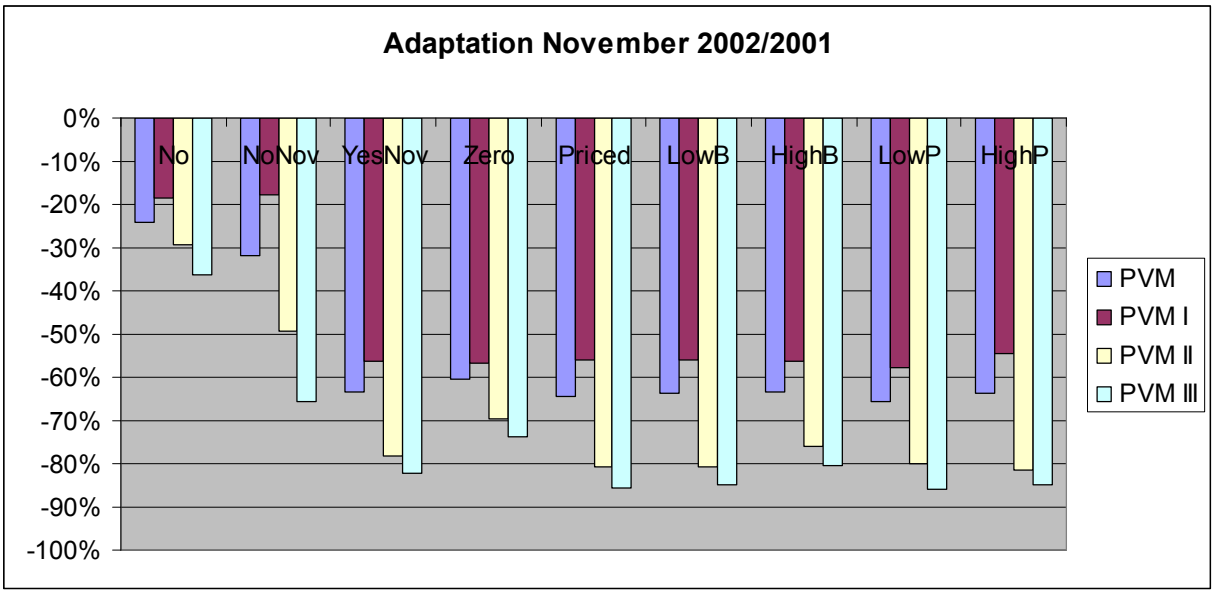
It is possible that we observe a 'relative price' effect in October – participants with the high bonus realise that their behaviour has a very small impact on their monthly net payment. Consequently, they do not care so much about their speed charges. This effect could also be behind the observation above, i.e. the price level is less important for the high bonus group.

3.3 Prolongation with equal bonus

The experiment was prolonged with one month, November 2002. All previous participants were given an offer to continue the experiment. Everyone, would receive the same low bonus (250 SEK). Over 85% of the participants accepted to continue the experiment. Around 87% of the low-bonus group continued but only 83% of the high-bonus group. Surprisingly, only 50% of the zero-priced group wanted to continue but 88% of the priced group[2].

[2] 91% for low price group and 84% for high price group.

Figure 5 Relative adaptation November 2002 compared to November 2001



As for the participation in the original experiment, drivers that did not want to continue in November has a significantly lower average age (7 years younger). We also found that drivers who wanted to leave the experiment were to a higher degree female drivers. They also drove a significant longer distance during the month November previous year. Two noticeable effects are observed; *first*, drivers that wanted to leave the experiment hade made a stronger adaptation than drivers that wanted to continue for the more severe violations in October. However, in November this difference disappears. *Secondly*, drivers that wanted to continue displays a stronger adaptation in November than the group that left the experiment for the aggregate violations and less severe violations.

Both participants and non-participants in the prolongation reduced their PVM from 11% to 16% prior to the experiment down to between 5% and 8% during the experiment. The reduction is between 40% and 50% for both groups as can be seen in the figure above. However, drivers that left the experiment increased their PVM to 10% in November, but it is still lower than the same month previous year and the reduction is around 30%. The participants, on the other hand, had a reduction with over 60% compared to November 2001.

The observation supports the general conclusion from the previous months, participation in the experiment significantly reduces the speed violation. This is not only true for drivers that enter the experiment and 'improve' their behaviour, but also for drivers that exit the experiment and 'worsen' their behaviour.

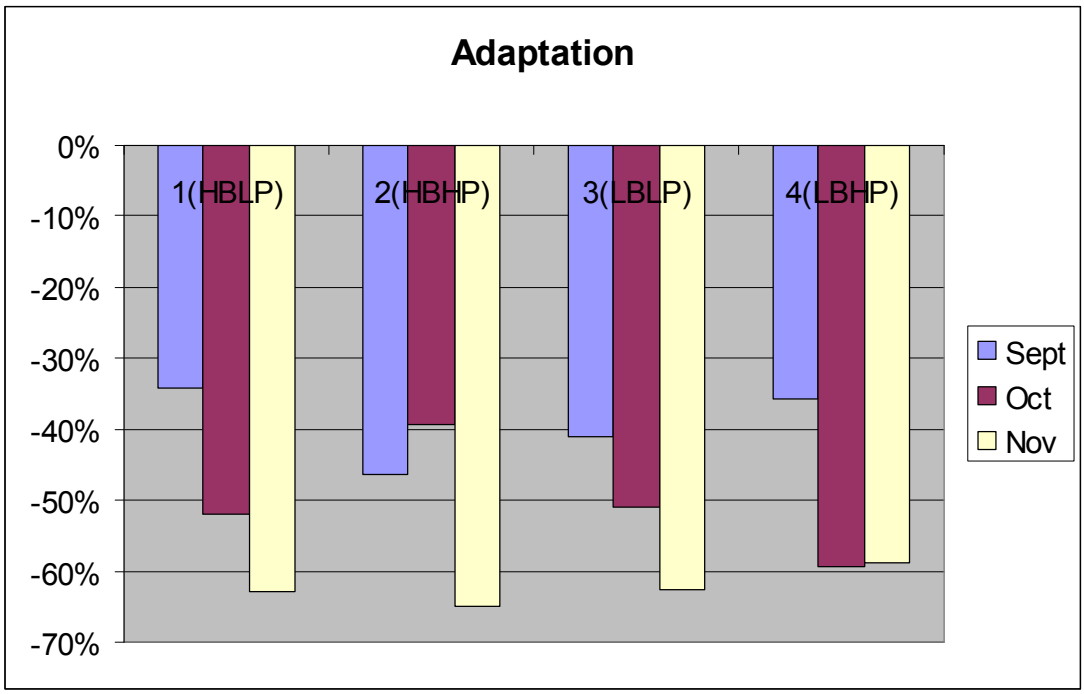
In the November experiment all participants received the same bonus. During October, the low-bonus participants that continued in November display a stronger adaptation than the high-bonus participants, which is the same tendency as for all participants in October. However, in the November experiment, when all users received the same low bonus, this difference disappears. In fact, when all users receives the same low bonus the possible 'relative price effect' disappears, and both groups commit speed violations around 5% of their time comparing to 13%-14% prior to the experiment.

If an assumption about a 'relative price effect' holds we should observe the strongest price effect for the high priced low bonus group and the weakest effect for the low priced high bonus group. When everyone receives the same bonus we should observe an equal behaviour.

The figure below presents the relative adaptation for the participants in the November experiment by group. Group 1 and 2 had high bonus while group 3 and 4 received the low bonus, group 1 and 3 faced the low price while group 2 and 4 met the high price.

Most groups continuously improved the behaviour with an increasing adaptation as the experiment continued. In October we notice the strongest adaptation for the low bonus high priced group 4, which supports an assumption of a 'relative price effect'. However, the lowest adaptation in October can be found for the high bonus group with the high price (2). Finally, in November, all priced groups display almost the same relative adaptation, which means a strong improvement of group 2 after their bonus was reduced.

Figure 6 Relative adaptation for each month (compared to same month previous year) by group 1 to 4 (HB=High Bonus, LB=Low bonus, HP = high price, LP=Low Price.



The reduction in the bonus level made the behaviour of the groups more equal. Although the evidence is not unambiguous it could suggest a 'relative price' effect, i.e. when the bonus becomes high enough the importance of the deductions declines. Together with the small difference in participation in the prolongation (83% for low bonus and 87% for high bonus) this suggest that the experiment does not gain from a too high bonus level.

The significant difference between priced and zero-priced participants are maintained during the prolongation of the project. In addition, the significant stronger adaptation for the high priced group is also observable during the November experiment if the experiment month is compared to May 2002.

4. Discussion and Conclusion

In an interview with the drivers at the end of the experiment two comments should be highlighted. First, numerous drivers described the price effect - *'although the price is very low it hurts to know that I have to pay when I violate the speed limit'* was a representative statement. This is mirrored in our result, both as we notice a difference between priced and zero-priced participants but it may also explain the rather weak difference between price levels. Secondly, some zero-priced drivers explained that they found the information very interesting and was competing with themselves to improve their behaviour. The information we gave the participants was the first time they saw an individual record of their behaviour and could thus have influenced the behaviour.

In conclusion, the experiment has shown that safe driving can be rewarded and that such a system will significantly reduce the speed violations committed by the participants. A system with progressive deductions will have the strongest impact on the most severe violations. The behaviour adaptation grow stronger as the experiment continued. The experiment has also revealed a possible 'relative price' effect in such a way that the price effect declines with increasing bonus. In short we summarise our observation in the following:

- Drivers that accept to participate in the economic experiment tends to be older, commit less speed violations and drive slower than non-participants. During the economic experiment participants significantly reduced their speed violations compared to non-participants. The proportion speed violations was reduced from around 15% of total driving time prior to the experiment to between 8% and 5% during the experiment with the lower interval at the end of the experiment period. Non-participants had almost constant proportion violations during the experiment.

- During the first experiment month the priced participants reduced the speed violations more than the zero-priced participants but the difference was not significant. However, during the second month priced participants reduced their severe violations (type II and III) significantly more than the zero-priced group, the former had a reduction of 64% while the latter only had a reduction of 15%. This effect was maintained during the third month.

- The low priced group had a significantly lower reduction in speed violations compared to the high priced group if we make the comparison with their behaviour in May. The difference between the two priced groups are in general smaller than between the priced and zero-priced group.

- We observe a tendency that the low bonus group made bigger reductions in speed violations than the high bonus group.
- In the prolongation during November it is observed that drivers who decided to leave the experiment was younger drivers and their reduction in speed violations was reduced when they left the experiment.
- The tendency from October, that low bonus participants had a stronger adaptation than the high bonus group, vanish when everyone receives the same bonus.

5. References

Armelius, H. (2003) , ‚Introducing congestion tolls that really will reduce congestion – and not just shift it to another mode.' Unpublished working paper, Dept. of Economics, Uppsala University.

Baumol, W.J. and Oates, W.E. (1988) The Theory of Environmental Policy. Cambridge University Press.

Boyer M. and G. Dionne (1983) 'Sécurité routière : efficacité, subvention et réglementation', Université de Montréal, Publication #3030, Juin 1983.

Hau, T.D. (1994) ‚A Conceptual Framework for Pricing Congestion and Road Damage'. In B. Johansson and L.-G. Mattsson Road Pricing: Theory, Emprical Assessment and Policy. Kluwer Academic Publishers.

Hurst, P.M. (1980) 'Can Anyone Reward Safe Driving?' Accident Analysis and Prevention, Vol 12, 1980, pp 217 – 220.

Janson, J.O. and G. Lindberg (1997) "PETS - Pricing European Transport Systems - Pricing Principles" European Commission 1997.

Jansson, J.O. (1994), Accident Externality Charges, Journal of Transport economics and Policy, Vol 28. No 1, pp 31 - 43.

Johansson, O. (1996), Welfare, externalities, and taxation; theory and some road transport applications. Gothenburg University.

Jorgensen, F.J. and J. Polak (1993) The effect of personal characteristics on driver's speed selection: an economic approach, ' Journal of Transport Economics and Policy 27.3, 237 – 252.

Lindberg, G. (2000): Marginal Cost Methodology for Accidents. UNITE (UNIfication of accounts and marginal costs for Transport Efficiency) Working Funded by 5th Framework RTD Programme, Interim Report 8.3. ITS, University of Leeds, Leeds.

Lindberg, G. (2001): Traffic Insurance and Accident Externality Charges, Journal of Transport Economics and Policy, Vol. 35, Part 3, pp 399-416.

Vägverket (2002) 'Borlänge – Resultat av ISA-försöket', http://www.isa.vv.se/novo/filelib/pdf/borlnge.pdf

Nilsson, G., (2000) 'Hastighetsförändringar och trafiksäkerhetseffekter: "potensmodellen"' VTI-notat 76-2000

Shogren, J.; T. Crocker (1991) ' Risk, Self-protection, and Ex Ante Economic Value', Journal of Environmental Economics and Management, 20, 1-15.

Vickrey, W. (1968), Automobile accidents, tort law, externalities, and insurance. Law and Contemporary Problems, Summer.