This paper draws on a cost-benefit study of vapour recovery systems for gasoline stations. These greatly reduce the exposure of the motorist to vapour from gasoline. The benefits are estimated both by questionnaire and by an experiment involving actual payments. Both methods indicate that benefits, as measured by willingness to pay, are far in excess of costs and hence that the technique is socially profitable.

Cet article est basé sur une étude avantage-coût des systèmes de récupération de la vapeur pour les stations d'essence. Ces systèmes réduisent grandement le temps d'exposition du motoriste à la vapeur d'essence. On évalue les avantages à partir d'un questionnaire et aussi au moyen d'une expérience basée sur les paiements réels. Les deux méthodes indiquent que les avantages, mesurés par la disposition à payer, dépassent de beaucoup les coûts et que la technique est donc rentable au point de vue social.

The Value of Clean Air: Consumers' Willingness to Pay for a Reduction in Gasoline Vapours at Filling Stations

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Introduction[1]

Many key "goods" that must be taken account of in environmental economics are non-traded and have no market price. Because of the difficulty of directly estimating the value of health and environmental damage, it has become common practice to make use of the "willingness to pay" (WTP) of those concerned as a measure of economic value (see Cummings *et al* (1986) or Mitchell and Carson (1989)).

This is not to suggest that WTP is a perfect measure. Obviously the values of some goods are not correctly reflected by individual willingness to pay. Furthermore, there are philosophical and methodological problems involved in measuring social utility by simply adding individuals' willingness to pay (see, for example, Elster (1985)). As well, the results are subject to the same problems of interpretation, associated

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with the distribution of benefits and with imperfect information, encountered in any evaluation based on market mechanisms. (The poor can hardly affect policies at all and the badly informed or misinformed may not be able to do it in accordance with their real preferences.) However, although imperfect, assessing WTP is one of the few methods available to the economist who wishes to account for non-market goods such as environmental quality.

Questionnaires are the most common way to measure WTP, but their use has been subject to criticism. It is argued that you cannot measure people's preferences simply by asking them — you have to observe them in action. As an alternative, experimental methods that involve actual payments have been suggested. However, such experiments are not always possible; nor are they always free of shortcomings of their own, depending on the character of the particular environmental good being studied.

In this paper both methods are applied: we have used a questionnaire and an experiment for our estimation of the WTP for gasoline vapour recovery systems.

Background: Gasoline Vapour Recovery

The particular environmental problem studied here is the emission of hydrocarbons at gasoline stations. The amount of vapour in a car's tank increases as gasoline is used up. Each time the tank is refilled, the vapour is pushed out from the tank. The emission factor depends on temperature and other circumstances, but is roughly 0.2% of the total amount of fuel purchased. The quantity of pollutants thus emitted is not negligible and, as the vapours are emitted literally under the nose of the motorist, human exposure is significantly larger than the quantities themselves would suggest. Thus we can treat these vapours principally as an individual health hazard (although they are, of course, also a general environmental problem).

Emissions can be reduced by well over 90% (see Berglund (1987)) if the gasoline stations install a recovery system that recycles the vapours back to its underground storage tank. Such systems are mandatory in California and some other US states.

To measure the cost of the equipment and its installation was relatively straightforward. We estimated it to be in the range of 0.5-1.5 Swedish öre per litre of gasoline sold (six öre are roughly equivalent to one US cent), depending on the rate of discount, on the turnover of the station, on whether other maintenance or construction work is being carried out, and so on. The value of the recovered gasoline is around 1/4 öre per litre, leaving a net average cost of roughly 0.25-1.25 öre for an average station. The price of gasoline in Sweden was, at the time (September 1987), just over 4 kronas including tax (1 Swedish krona = 100 öre = 0.16 US$).

To evaluate the benefits of recovery or, conversely, the environmental cost of emission, was more difficult. The damage caused by a specific pollutant is hardly ever known exactly and the combined effects of different sources and forms of pollution are even more difficult to evaluate. Another problem is that even if medical and ecological effects could be quantified with precision, the "value" of the ensuing pain, grief and anxiety would still be impossible to evaluate. Therefore we chose to use willingness to pay (WTP) of consumers (motorists) as the best available measure.

Measuring Willingness to Pay

A willingness-to-pay approach can help avoid the underestimation, through omission, of "non-tangibles" because it can in principle include the whole range of effects of which the individual is aware: ecological, medical, psychological, moral, aesthetic and so on. It also includes an implicit rate of evaluation of future goods. It does, however, lend itself to another form of underestimation if the respondents do not fully include items that may affect them only indirectly or to a very minor extent, such as the costs of health care, loss of production, automobile corrosion and so on (Jones-Lee *et al*, 1985).

There are two main ways of measuring WTP: either by asking consumers what they would be

willing to pay *if* they could choose to "buy" the non-market commodity; or by observing a situation in which consumers actually make a choice and pay for it. The latter can be done in two ways. Sometimes suitable markets exist and can be studied. (Examples of such markets are those for the use of land and for travel. One can observe the land market in order to use differences in property prices to estimate the values attached by homeowners to particular environmental qualities. Similarly one can observe how much people are willing to pay to travel to a certain location that has attractive environmental characteristics.) In other cases the researcher may conduct an experiment, creating a more or less realistic "commodity."

A questionnaire might involve various potential biases, which have been discussed in the literature. Most relevant for our study are the following:

1. **Strategic bias** has been extensively discussed in relation to public goods[2] (the so-called "free-rider problem"). Do respondents deliberately misrepresent their preferences in order to influence the outcome of the research? If no actual payment is involved or if an actual payment is not related to the individual respondent's reply, consumers who favour expenditure on a public good might overstate their WTP in order to increase the average WTP observed and hence the likelihood that the project is realized.
2. Respondents may also have genuine difficulty in knowing what they would be willing to pay in a hypothetical situation. This **hypothetical bias** should be stronger the smaller the practical effect each respondent expects his or her answer to have, while the reverse applies to incentives for strategic bias.

The exact formulation of the question is yet another potential source of error. The scenario suggested may affect the realism of the question and it may offend the respondents' sense of justice. If a survey estimates willingness to pay for a public service, responses may be different depending on whether the questionnaire is seen as suggesting tax-financing or a charge on the consumer. Also, the question "how much would it be worth if you had to pay" is easily taken to imply that you actually ought to do so.
3. Since the issues involved are quite complex and uncertain, the information on health hazards and risks available to the respondent is crucial for the response. **Information bias** can be restricted but not eliminated. It should be kept in mind, however, that many market transactions take place with far from perfect information.
4. As with any kind of survey, it is essential to know that the sample is indeed representative and that the response-rate is sufficiently high.

A number of attempts have been made to estimate the extent to which these and other sources of bias distort measurements of WTP. Bohm (1979) and Bohm and Nilsson (1981) have studied strategic behaviour by giving one group of respondents incentives to exaggerate their WTP and another incentives to understate it. The results have shown some strategic bias, but to quite a modest extent. Other, usually less realistic, experiments with public goods, such as those of Brubaker (1984) and Marwell and Ames (1981), report similar results: strategic behaviour exists, but there is no support for the "strong free-rider hypothesis" that every opportunity for free-riding is taken. Attempts to compare survey and hedonic techniques or hypothetical questions and actual payments (e.g., Bishop and Heberlein (1979) and Brookshire *et al* (1982)) have produced estimates of WTP of roughly the same order of magnitude.

Choice of Method

Our main method was a questionnaire survey. As an additional check, we also conducted an experiment.

We considered it essential that the sample included in our survey be truly representative of motorists in Gothenburg, since both attitudes to health hazards and to environmental protection

2/ A good is a **public good** if it is consumed jointly by more than one person at the same time and if the amount of it consumed by any one person does not affect the amount available for other consumers. National defence, radio broadcasting and clean air are examples that approach, as closely as is possible in a practical context, the state of being **pure** public goods.

The Questionnaire

Thirty-five questions were asked. The first nine concerned habits in relation to driving and gasoline-filling, including factors normally influencing the respondent's choice of filling station.

We then asked whether they had previous knowledge and experience of vapour recovery systems, their general opinion of these and who they considered should bear the costs of vapour recovery systems. These eight questions led up to the crucial questions:

- If gasoline were more expensive in stations with recovery systems, would you — distance, service and everything else being equal — find it worth paying more to use them?
- If so, how much would it be worth?

This was followed by two questions about the respondent's reasons for appreciating the recovery systems.

Four questions were asked about the respondent's need for a car and their view of motoring in relation to the environment. Two questions were asked about the respondent's interest in environmental issues. The last nine questions gave general background information about the respondent such as age, gender, children, income, type of occupation and political affiliation. A random subsample was given a different version of the accompanying information sheet, which played down the cost of vapour recovery to the consumer, and a correspondingly altered formulation of the willingness-to-pay questions. The subsample of Prajs customers were asked for more detailed views of the vapour recovery systems.

vary strongly among different categories of people. We also considered information bias to be a major issue, since a number of complex technological, medical and ecological issues were involved.

In this particular context we expected strategic bias to play a minor role. Not only do the above mentioned, earlier studies indicate this, but, furthermore, vapour recovery is not a pure public good, since the main beneficiary is the motorist him/herself. This property makes gasoline recovery more suitable for a direct measurement of willingness-to-pay than many other environmental goods.

Hypothetical bias could also be expected to be much smaller than if we had studied a larger and more complex issue, such as global carbon dioxide or ozone emission.

We reached the conclusion that an experiment with actual payments to real consumers was not a good method. Such an experiment would have required a gasoline station at the disposal of the investigators, where gasoline tanks could be filled with and without vapour recovery at different prices.

This was unfeasible for not only practical and financial reasons. Even if it had been possible, it would have been difficult to generalize from consumer behaviour under such experimental circumstances. We would have known very little about how representative the respondents were, or about their motives — whether it was preference, curiosity or simply the length of the queues that determined their choice. It would also have been difficult to inform respondents properly. If instead we had used two different stations, one with and one without vapour recovery, these problems would have been even greater and the difference in location would have introduced yet another source of bias. Finally, the existing gasoline stations with recovery systems could not be expected to allow us to vary their prices at our pleasure!

A questionnaire, in spite of any deficiencies of hypothetical, and perhaps strategic, bias was preferable to an alternative that involved such problems of sample and information bias. We therefore chose to distribute a questionnaire to a representative sample of Gothenburg households and to complement it with a small scale experiment designed to indicate differences between hypothetical and "actual" behaviour in two comparable samples.

The Survey and Its Results

The questionnaire, together with an information sheet, was distributed to 800 respondents. (A

description is provided in the box set out above.) Six hundred of these were a random sample of the population, aged 18 and upwards.[3] A control group of 200 consisted of customers of a local gasoline company, Prajs, whose stations are equipped with vapour recovery systems. These 200 respondents therefore had previous knowledge of and experience with the system.

The question of greatest interest in the context of an economic analysis — a quantitative measure of the utility of the vapour recovery system — was the most difficult for respondents to answer. When designing the questionnaire we tried to "pave the way" by including questions on the respondent's attitudes, as well as driving habits and the choice of gasoline stations. (See box.)

We tried (and to a large extent succeeded) to prevent non-motorists in the sample from lowering the response rate by urging them to return the questionnaire. Telephone interviews were used to give an estimate of the percentage of motorists among non-respondents. Hence we could estimate the rate of response among motorists in the random sample to be approximately 70%.

The mean WTP was 15.7 öre per litre of gasoline, the median 5 öre. For a more accurate measure of consumer surplus, we also calculated the average WTP weighted by the amount of gasoline annually purchased. This was 11.9 öre (that is, around 3% of the price of gasoline). The distribution of WTP is described in Table 1.

We could not, however, treat the respondents as representative of the sample as a whole. Those in favour of recovery systems had stronger incentives for replying. Our telephone interviews confirmed that WTP was lower among those who had not replied. Using the telephone interviews we were able to estimate mean WTP of the entire sample at 9.4 öre per litre, when weighted by gasoline purchases. Having consistently made assumptions that would tend to underrather than overestimate the mean WTP in this estimate, we are confident that the true figure is not less than 9 öre per litre.

Social Determinants of Willingness To Pay

The differences in mean WTP that immediately emerged between different groups of respondents were quite large. The average WTP of women (23 öre per litre) was almost twice that of men (12 öre). Younger respondents (under 35) were willing to pay about three times as much as those over 50. Gender differences were much smaller among the young. (See Table 2.) The relation between income and WTP was insignificant and, if anything, negative.

For an analysis of how WTP varies in the presence of several exogenous variables we present the results, in Table 3, of two alternative linear regressions.[4]

Regression analysis confirmed the importance of age and gender as determinants of WTP. Table 3 shows coefficients of 7.9 and 7.2 for the variable "gender" (defined as 1 for women and 0 for men), implying that the WTP of women was 7-8

3/ A sample of motorists only would, for practical reasons, have meant "car owners" and, since a car used by two spouses is more often registered in the name of the male, this would have introduced a gender bias in the sample.

4/ Actually, ordinary least squares (OLS) estimates are biased and inconsistent when the distribution is truncated. In our case, only non-negative values of WTP were feasible and about 13% of the respondents answered "zero."

The Tobit approach (defined below) avoids this by distinguishing between the different effects that an independent variable (X_i) may have. Firstly it may affect the probability of the dependent variable being non-zero; secondly, it may then influence its size (see Tobin (1958) and Flood (1987)).

$$Y_i = a + \beta' X_i + e_i \qquad e_i \sim N(0, s^2)$$

$$Y_i = Y_i \text{ if } Y_i > 0$$

$$Y_i = 0 \quad \text{otherwise}$$

Our Tobit estimates are not reported here. They are, however, available on request from the authors (in both linear and logarithmic models). The differences between OLS and Tobit estimates were small. All parameters that were significant in OLS were of the same sign and very similar order of magnitude in Tobit. It thus seems that the "truncation" of our data was not severe enough to seriously bias the OLS-estimates. Since the interpretation of the OLS parameters is more straightforward, we will use them in the following discussion.

Table 1: Distribution of WTP

WTP (öre/l)	% of respondents
0 - 2.5	27.3
2.5 - 7.5	24.4
7.5 - 12.5	18.5
12.5 - 32.5	14.8
32.5 - 52.5	9.6
52.5 - 100.0*	5.4

* Values above 100 öre have been set to 100

Table 2: Average Willingness to Pay by Age and Gender (öre/l)*

Age (y)	Women	Men	Average
<24	29.1 (9)	21.1 (23)	23 (34)
24-34	25.0 (26)	19.5 (36)	22 (63)
35-49	24.5 (36)	6.7 (39)	15 (75)
50-64	16.1 (7)	4.6 (34)	6 (42)
>65	12.2 (6)	8.0 (15)	9 (22)
Average	23 (85)	12 (148)	16 (238)

* numbers in parentheses represent number of respondents

Note: The average for each age group includes those who did not answer the question about gender and conversely for the average for the gender groups. This explains the discrepancies between the first two columns and the third and between the first five rows and the sixth.

öre higher than that of men. The parameter for "age" was approximately -0.2 to -0.3 öre per year, which means that with 10 years difference in age, the older respondent is statistically expected to have a 2-3 öre lower WTP. The coefficient for income was negative, but not significant even at the 10% level. The absence of a positive dependence of WTP on income, that one may have expected, may be attributable to the small sums of money involved — the median *annual* WTP (taking mileage into account) was around $10 (US).

WTP also turned out to depend very significantly on the respondent's views on motoring in relation to the environment. Respondents who agreed with the statement, "cars are always a serious environmental hazard," had a very high WTP: the parameter for this dummy variable was 10 öre and significant at the 1% level, while

Table 3: OLS-Estimates of WTP Using Two Different Linear Regressions

Parameter	Regression 1	Regression 2
Intercept	27.1	29.9
Gender[1]	7.9**	7.2**
Age	-0.24**	-0.27**
Income (Skr x 10^4)	-0.13	-0.16
Annual driving distance (km x 10^3)	-0.22**	-0.19*
Experience of recovery systems	4.2	4.2
Has children		3.2
Dependent on having a car		-2.9
Holds account with a gasoline company	-2.2	-3.2
Choice of station determined by price		-1.6
Considers that only the companies ought to pay	-6.6**	-6.8**
Given less information		-4.4
Prajs customer		0.4
Considers motorism a serious environmental problem	12.1**	9.9**
Disapproves of restrictions on motorism		-1.7

* Significant at the 10% level
** Significant at the 1% level

Note:
1/ "Gender" was set to 1 for women, 0 for men.

the response solicited by the more general question, "Are you highly interested, rather interested or not very interested in environmental protection?" was not significant at the 10% level. Party political sympathies could not be shown to affect WTP significantly. (With a high rate of non-response to this question and with seven

political parties, most of the subsamples became very small.)

Reliability of the Result

The raw data showed that customers of Prajs (who were familiar with the recovery system) surprisingly indicated a lower WTP than the random sample, only 9.5 öre per litre. This appears, however, to be explained by a non-typical customer profile for this company: in linear regressions, the difference in WTP became insignificant as soon as age, gender and annual driving distance were included. With more variables included it even became positive. This result agreed with the view expressed by the Prajs customers. Eighty percent of them stated that they would "much rather" use a gasoline station with vapour recovery, a majority thought it "more healthy" and only 15% had experienced any inconvenience. The unusually high rate of response in this group, 88%, can presumably also be seen as an indication of appreciation.

That these positive attitudes did not result in a significantly *higher* WTP in this subsample appears to be, at least partly, due to another factor. The economist asking for "willingness to pay" is out to quantify "utility" and wants to make a clear distinction between a monetary measure of "what it's worth" and the distributive or ethical issues of "who ought to pay" and "what should be allowed." Respondents, however, may not think quite in those terms. In our study there were three likely pitfalls in communication between researchers and respondents:

1. A common reaction to willingness-to-pay measures of environmental quality is that it is "wrong to put a price on the environment." People with a strong concern for environmental protection often find this unethical and some express their disapproval by answering that they would not pay anything. In a quantitative analysis this comes through as no value being attached to the environmental good at all — an obvious underestimation.
2. Several participants commented that they would "pay what it costs" for vapour recovery. Response may therefore reflect an attempt to guess "how much could it cost" rather than "how much would it be worth to me."
3. A related and recurrent problem in willingness-to-pay surveys is to know how people will respond if they do in fact value a public good, but do not consider it right that they have to pay for it. This turned out to be highly relevant for our study. A majority of motorists in the random sample considered that the gasoline companies ought to bear some part of the cost of vapour recovery and this group had a significantly lower WTP. A third of the sample felt that the gasoline companies ought to bear the *whole* cost and stated an even lower WTP. In the linear regression, agreement with the statement "only the companies should pay" corresponds to a parameter of approximately -7 öre, significant at the 1% level.

We informed respondents that vapour recovery implies a net cost. Judging from comments we received from some of them, they did not always believe us. Presumably, they were therefore reluctant to let the gasoline companies charge the consumer for something that "doesn't cost them anything."

For the Prajs customers in particular this would seem likely. Prajs, for reasons of competition, does not charge a higher price than other gasoline stations. A plausible explanation, supported by the regression analysis, for why this group claims to very much appreciate vapour recovery, yet doesn't want to pay very much for it, could be that they do not want to justify a price increase.

These three problems of interpretation of the question would suggest that our method leads to an underestimation of utility. Other misrepresentation is probably a smaller problem. The participants realized that each individual reply had little impact on the mean. (Furthermore, we truncated bids above one Swedish krona.) The result of the survey would not immediately or automatically govern a political decision on the issue. Hence the incentives for manipulative responses were very weak.

However, as an additional test for the existence of significant hypothetical or strategic bias, we carried out an experiment.

The Experiment

Since no existing markets (for property etc.) provided us with a plausible indirect measure of WTP, the only way to check for hypothetical bias was to experiment with make-believe "commodities": "gasoline with vapours" and "gasoline without vapours."

To investigate this form of bias we asked students to take part in an experiment. One-third of the participants (the "hypothetical" group) was asked only to answer a questionnaire and to give a hypothetical bid for "gasoline without vapours." The remaining two-thirds (the "experimental" group) were given a month to fill their cars with gasoline at one of two filling stations that we had chosen. These two stations were located within a few blocks of each other and their prices were the same. One was equipped with a vapour recovery system, the other was not.

We promised every participant a modest compensation for their trouble and also created a price differential by making the compensation larger for those who chose the station *without* vapour recovery. For one half of the group "gasoline without vapours" cost two öre more per litre than "gasoline with vapours," for the others the difference was ten öre.

Obviously, generalizing from experiments involving students can be highly questionable. The WTP of these students was not considered representative of the population at large. The sole point, however, was to compare the two student groups with each other.

Of the 34 students in the hypothetical group, 28 were willing to pay at least two öre extra per litre for "gasoline without vapours." Eleven said that they were willing to pay at least 10 öre.

The main difficulty we faced was to persuade the 69 students, who had promised to fill up with gasoline at one of the two stations, to actually do so. Only 24 of them completed the experiment. Of those faced with a price difference of two öre, all 11 chose the station with vapour recovery. Of the others, 12 out of 13 chose to forego 10 öre per litre in order to avoid the vapours.

A *t*-test shows that WTP in the experimental group is significantly higher than that in the "hypothetical" group. The problem is that the low response rate makes the results uncertain.[5] Our conclusion, however, was that in this experiment willingness to pay was not lower than in the corresponding hypothetical replies.

Another problem with an experiment of this type is that the participants' behaviour in a once-off purchase situation may be just as hypothetical an answer to the question of their long term WTP as a reply to a questionnaire. This problem will apply to any short term experiment, particularly if only small amounts of money are involved. To avoid it, the researcher would have to follow a sample of consumers over a period of time, say six months or a year. Such a study would be very interesting from the point of view of methodology, but it would require very large amounts of time and money. (Quite out of proportion to the cost of the vapour recovery system!) And even if this could be done, there would still be a severe problem of representativity. Considering the differences between groups of motorists, this would be a serious problem.

Conclusions

This study, like all other attempts to estimate WTP, is subject to a degree of uncertainty. Both the literature in the field and our analysis of possible sources of bias indicate that these are of manageable size. Given the conservative assumptions made on many points and our finding that the willingness to pay stated by consumers still exceeds the costs of 0.25-1.25 öre by 10-20 times, our conclusion that gasoline vapour recovery systems provide a social gain seems difficult to doubt.

The study shows realistic and consistent results from a survey of consumer WTP. A comparison of the survey and experimental results

5/ Note, however, that even if we make the extreme assumption that all those who failed to complete the experiment would have chosen the station without vapour recovery, we still find a higher WTP among those actually paying in the "ten-öre group," compared to the hypothetical answers, but this was not the case in the "two-öre group."

does not indicate any major discrepancies that could be ascribed to strategic behaviour.

The linear regression analysis showed significant variation in response between subgroups, in particular age and gender groups. Hence it underlines the importance of a representative sample. It also shows that, in contingent valuation, great care must be taken to analyze possible misunderstandings between researcher and respondents.

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