Willingness-to-Pay for Improved Air Quality in Hamilton-Wentworth: A Choice Experiment

Alan A. Diener
R. Andrew Muller
A. Leslie Robb

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Department of Economics, McMaster University
Hamilton, Ontario, Canada
L8S 4M4

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Correspondence:
Alan Diener, E-mail: dienera@mcmaster.ca; or
R. Andrew Muller: E-mail: mullera@mcmaster.ca

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1. Introduction

Although air pollution is often viewed primarily as a health problem, other aspects also require attention. Poor air quality exacerbates cardiac and respiratory conditions and may increase hospitalization rates and mortality (Dockery and Pope, 1994; Burnett *et al. 1995*). There is evidence, however, that the so-called nuisance or aesthetic effects of poor air quality are also important to the general population. For example, 70% of respondents living in the industrialized north end of Hamilton reported a concern with black particulate deposition (black fallout or black soot) (Elliott *et al*., 1997). The most frequently cited effects of black soot concerned “lifestyle disruption”, including property damage to cars and furniture. Although almost half of those complaining about black soot considered it a health problem, current research indicates that the particulates most dangerous to health are much smaller than those implicated in black fallout, so the damage done by this type of air pollution is unlikely to be reflected in medical statistics. Thus studies which infer the benefits of air pollution control from avoided health risk are likely to underestimate the true benefits and must be supplemented by some estimate of willingness-to-pay for other dimensions of improved air quality.

Since there are no specific market transactions for the attributes of air quality, we must rely on non-market valuation methods. Revealed preference, or indirect, methods focus on inferring willingness-to-pay from data on actual behaviour. For example, it is possible to infer some measure of willingness-to-pay for improved air quality indirectly through market phenomena such as housing prices. Recently, however, stated preference approaches have become increasingly popular. These methods use surveys to assess willingness to pay directly. The most popular stated preference approach is contingent valuation, in which respondents are presented with a carefully described but hypothetical choice between two alternatives. They are then asked directly how much they would be willing to pay for their preferred alternative, or conversely, how much they would be willing to accept to forego their preferred alternative. The debate on the validity of contingent valuation (see Portney, 1994, Hanneman, 1994, and Diamond and Hausman, 1994) has not been concluded, but there is a general opinion that carefully designed studies can reveal useful information at least about the order of magnitude of environmental benefits. Because it usually focuses on the detailed description of just two scenarios, however, contingent valuation faces significant problems in separating out the values placed on the individual attributes of a multi-dimensional service such as air quality. Thus the health and non-health effects of air pollution have generally been valued independently (Loehman and De, 1992; Hall *et al*. 1992[1]; Schechter 1989 and 1991; Rowe *et al.*, 1980).

Choice experiments offer a promising opportunity to explore the value placed on environmental services with multiple attributes. This technique is based on the conjoint metric analysis methodology developed in the field of marketing by Louviere (1988) and extended to the environmental economics literature by authors such as Adamowicz *et al.*(1994) and Schulze *et al*. (1995). Conjoint analysis has also been employed extensively in the economic evaluation of health care (Ryan *et al*.) In a typical choice experiment respondents are asked to choose their most preferred choice from a set of alternatives, where each alternative is described by the levels of a number of attributes. One of the attributes is a payment vehicle such as an admission fee or a

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[1]Although Hall et al. did not conduct an original contingent valuation survey, they reviewed several studies that attempted to value the health effects of air pollution.

level of property taxes. The responses are then analysed in a quantal response framework of the type developed by McFadden (1974) and manipulated to measure willingness-to-pay by the estimated trade-off between the payment vehicle and the other attributes.

The choice experiment methodology has both advantages and disadvantages. It seems to reduce the number of protest responses, especially those involving tax increases or willingness-to-accept environmental degradation in return for payment. It also increases the amount of information obtained from each respondent, thus reducing the required sample, and hence the costs, of surveys. Even more information can be extracted from individual responses if the complete ranking of scenarios is analysed instead of simply the first choice. It has been shown that by taking advantage of the additional information contained in the ranking of preferences, the parameters of the random utility model can be estimated more efficiently (Chapman and Staelin, 1982). On the other hand, describing the scenarios convincingly requires considerable effort and it is not clear that the average respondent is able to understand the implicit trade-offs. Moreover, a full exploration of a single individuals' preferences can be both time consuming and cognitively difficult. Relying on personal interviews to offset these difficulties can significantly increase the cost of the survey. In summary, more experience with choice experiments will be required before they are well integrated into environmental valuation.

In this paper we report a choice experiment conducted to value the benefits of improved air quality in the Regional Municipality of Hamilton-Wentworth, Ontario, Canada. The survey was conducted by mail. Respondents were presented with well-defined alternative scenarios involving four attributes of air quality (health effects, bad odour, black fallout and poor visibility) and one payment vehicle (property taxes or rent). The substantive goal of the research was to provide credible estimates of the willingness-to-pay for each of these broadly based attributes, in order to inform policy initiatives being undertaken at the Regional level. Methodologically, the experiment was designed to detect and assess the effects of cognitive difficulties among respondents and to explore the gains available from employing rank orderings of the choice set alternatives. Our results also demonstrate the feasibility of conducting complex choice experiments by mail.

The next section reviews the methods used in the survey, including the general design of the questionnaire, the derivation of the attribute levels, and sample selection. Section 3 presents the econometric model used to estimate willingness-to-pay. Section 4 presents results. Section 5 concludes with a general discussion.

2. Methods

2.1. Questionnaire Design

The questionnaire comprised three sections.[2] The first was intended to measure respondents' concerns about air quality relative to other social issues, to familiarize them with the air quality attributes being evaluated, and to elicit information about their past experiences with the attributes. It began by asking respondents to compare their air quality to that of the rest of southern Ontario, followed by four questions asking how concerned the individual was about each of the air quality attributes of odour, black fallout, poor and health. Since these had not yet been defined or described, the responses should be unbiased of framing effects. Further questions

[2] A copy of the questionnaire is available upon request.

described each attribute in detail and asked for the respondent's experience with that attribute. Featured in this section was a colour photograph of a hazy day. The section concluded with a pie chart illustrating the share of various services, such as education and policing, in the Regional property tax bill for a typical household (Figure 1). The second section, described in detail below, contained the choice experiment scenarios and the final section elicited demographic information.

We conducted two pilot studies. In the first, we mailed 30 questionnaires to a random sample of residents in the City of Hamilton. This study demonstrated that, despite the complexity of the choice sets, we might expect a response rate of about 30%. In the second pilot study we administered the questionnaire to a sample of 189 undergraduate economic students at McMaster University. This study demonstrated the feasibility of the computational technique employed to estimate the willingness to pay for improvements in the air quality attributes. The two pilot studies also led us to revise the wording and placement of several questions in the survey.

2.2. The Attributes

The air quality attributes were (i) health effects, described as increased mortality and hospital admissions due to cardio-respiratory diseases, (ii) number of days of black fallout, (iii)number of days of bad odour, and (iv)number of days of poor visibility. We used three levels of each attribute. The middle level of each attribute corresponded to the status quo. The other two levels were a one-third reduction and a one-third increase in the current level of the attribute. Table 1, extracted from the questionnaire, shows how each of these levels was defined.

The health effects were described as hospital admissions for cardiac and respiratory diseases in the Region of Hamilton-Wentworth and increased mortality. As previously stated, many of the studies that have attempted to value the health effects of air pollution have focused on personal effects only (e.g. Hall *et al.*, 1982). Given that people may, and do, care about the well-being of others in society it is important to frame questions in such a way that these externalities are accounted for. Thus, rather than estimate the willingness to pay for a reduction in personal health risk it may be more appropriate to frame questions from a societal perspective. For example, "How much would you be willing to pay to decrease society's health risk?" In this way such externalities can be accounted for. Using hospital admissions and regional mortality captures such externalities. The changes in the attributes were all specified in certain terms and in actual changes, rather than percentage reductions. This was done in order to avoid the added complexity of understanding how the respondents may have reacted to changes in risk (Schulze *et al.*, 1995).

The number of hospital admissions for cardio-respiratory diseases was calculated using the results of Burnett *et al.*'s (1995) study of the relationship between daily cardiac and respiratory admissions to 168 hospitals in Ontario with daily levels of particulate sulfates. They found that current levels of sulphate exposure led to increases of 2.5% and 3.5% in cardiac admissions (for those under and over 65, respectively) and 3.2% in respiratory admissions, compared with levels expected under zero exposure attributable to sulphate exposure. Since Burnett *et al.* only considered sulfates, the actual estimate for cardiac and respiratory hospital admission attributable to all air pollution would be larger. Table 2 indicates the diseases and ICD9 codes that were used by Burnett *et al.*

Applying Burnett *et al.*'s findings to annual data for Hamilton-Wentworth we estimated that approximately 128 (2.5% of 5108) cardiac admissions and 77 (3.2% of 2407) respiratory admissions were attributable to sulfates for a total of 205 admissions per year. For the purposes of the questionnaire we rounded this to 18 hospital admissions per month. Because Burnett *et al.* only considered exposures to sulphates, our estimate for hospital admissions from all types of air pollution is conservative.

The estimate of bad odour days was based on occurrences of total reduced sulphur (TRS) at the Beach Blvd. monitoring station. The five-year average of number of days with one or more hours over 10 ppb (49 days per year) was divided by 12 and rounded off to yield an estimate of 4 bad odour days per month under the current situation.

The estimate of poor visibility days was based on five-year average of number of days with one or more hours of the Air Pollution Index (API) being 25 or greater at the Elgin/Kelly monitoring station (14 days per year). Since these events generally only occur during the five months of April, May, June, September and October we expressed this as 3 days per month. The months of July and August may also experience poor visibility days due to factors not captured in the API. We have estimated that these summer poor visibility days occur at the same rate as the spring and summer poor visibility days and for purposes of this analysis have grouped them together.

Black fallout (BFO) is not monitored and the only available proxy was a monthly dustfall measure. Since this estimate cannot be used to ascertain the number of days of occurrences the estimate of high BFO days was based on complaints registered with the Ministry of Environment and Energy from the Beach strip area. The five year average of 36 days of complaints annually was expressed as 3 black fallout days per month.

Because they are frequently used to finance local services, we chose property taxes as a payment vehicle. Since not all respondents would be homeowners, the payment vehicle was described as a change in monthly property taxes *or* rent. People were told that increased taxes may be necessary in order to reduce pollution. A pie chart (Figure 1) was used to illustrate the average level and functional breakdown of the monthly tax payments on a typical property (Hamilton-Wentworth, 1996).

2.3 The Choice Sets

In Part B of the questionnaire respondents were presented with nine choice sets. Each choice set consisted of four alternative choices that were to be ranked by each respondent. Figure 2, extracted from the questionnaire**,** shows the Sample Choice Set used to explain the procedure. As in the actual choice sets, Choice A describes the status quo. The remaining choices were created by specifying differing levels for each of the five attributes. As noted, we used three levels (status quo, one-third better and one-third worse) for each of the air quality attributes. We used 13 levels of change in monthly taxes (no change plus increases or decreases of $5, $10, $15, $20, $25, and $50).

There are 2^4x13 or 1053 possible ways of combining the air quality attribute and tax levels to form choices. We restricted this set in two ways. First, we decided not to combine different increments in taxes within the same choice set. That is, the tax attribute within each choice set was restricted to three levels: an increase or decrease of one-third or no change.[3] This left 2^5 or

[3] For example, Choices B, C, and D in Figure 2 all involve a $5 change in taxes or rent.

243 choices from which to create choice sets. Since it was impractical to ask respondents to rank all of these, we used a one-ninth partial factorial design to choose 81 choices which we then divided into nine sets of three choices each (see Petersen, 1985, ch. 8,9, for a discussion of partial factorial designs). These sets were appended to Choice A (the status quo) to form the nine choice sets used in the questionnaire. We then created six versions of each choice set, one for each of the six possible increments in property tax ($5, $10, $15, $20, $25, and $50). Finally, we created six versions of the final questionnaire in such a way that every choice set was presented using each of the tax increment levels and every respondent faced each of the tax increment levels at least once. Table 3 reports the tax levels that were used in each version of the questionnaire. In all other respects the questionnaires were identical.

This procedure for generating choice sets produced some choices which were weakly dominated by others in the same set, in the sense that the level of at least one of its attributes was inferior to another choice and none were better. (We assumed that improvements in air quality attributes and reductions in taxes would always be preferred). As a result, 9 of the 54 possible pairwise comparisons in the nine choice sets involve a dominance relationship. We viewed this as a virtue of the design, because it allows a test for rationality of responses.

2.4. Sample selection

We administered the survey by mail because the complexity of the ranking exercises made it infeasible to conduct the survey by telephone and the cost of personal interviews would have been prohibitive. The final version, of the questionnaire, was sent to 1908 households within the

Regional Municipality of Hamilton-Wentworth.[4] The sample was randomly chosen from the regional tax assessment rolls as of December 1995. The survey packages, which included a copy of the questionnaire, a cover letter, and a prepaid return envelope, were mailed out on February 10, 1997. In order to encourage responses, we informed recipients that each respondent who returned a completed questionnaire by February 28, 1997 would be entered into a draw for one of ten $25 gift certificates to the local department store, or mall, of their choice. One week after the initial mailing, we sent a follow-up postcard reminding those who had not yet sent in a survey to please to so and thanking those who already had.

3. The Model and Willingness To Pay

We used a random utility model to infer willingness-to-pay. The utility derived by individual i from choice j can be expressed as

$$U_{ij} = \mu_{ij} + e_{ij} \qquad \textbf{(1)}$$

where V_{ij} is the observable, or systematic, component and e_{ij} is the unobserved, or random, component of total utility. The probability of individual i choosing alternative j is

$$P_i(j) = P(U_{ij} > U_{is}) \ \ \forall s \in C_i, \ j \neq s \qquad \textbf{(2)}$$

[4]Questionnaire types A, C, D, and E were each sent to 333 residents. Questionnaire type B was sent to 243 residents, and questionnaire type F was sent to 323 residents. Due to a clerical error, the same number of each type of questionnaires were not sent out. There were enough of each type returned such that the results were not significantly affected.

where C_i is the specific choice set facing the individual. We assume that utility, μ_{ij} , has the following linear form.

$$\mu_{ij} = \beta' X_{ij} = \beta_1 x_{ij1} + \beta_2 x_{ij2} + \beta_3 x_{ij3} + \cdots + \beta_k x_{ijk} \quad \textbf{(3)}$$

If the error terms, e_{ij}, are independently and identically distributed with a Weibull distribution, it can be shown that (McFadden)

$$P_i(j) = \frac{e^{\beta' X_{ij}}}{\sum_{j=1}^{J} e^{\beta' X_{ij}}} \quad \textbf{(4)}$$

We estimated two models. The first model was a full quadratic in all of the attributes. Dropping subscripts for convenience, utility was defined as follows.

$$\begin{aligned}\mu = {} & \beta_1 H + \beta_2 O + \beta_3 F + \beta_4 V + \beta_5 T + \beta_6 (H \cdot O) + \beta_7 (H \cdot V) + \beta_8 (H^2) + \beta_9 (H \cdot F) + \beta_{10} (H \cdot T) + \beta_{11} O^2 \\ & + \beta_{12} (O \cdot V) + \beta_{13} (O \cdot F) + \beta_{14} (O \cdot T) + \beta_{15} V^2 + \beta_{16} (V \cdot F) + \beta_{17} (V \cdot T) + \beta_{18} F^2 + \beta_{19} (F \cdot T) + \beta_{20} T^2\end{aligned} \quad \textbf{(5)}$$

where H = health risk
O = bad odour days
F = black fallout days
V = poor visibility days
T = property taxes or rent

Each of the air quality attributes is coded 0 for the initial situation, and +1 or -1 for one-third improvements or reductions respectively. Taxes were coded as deviations from the status quo, measured in dollars.

If we are calculating WTP from the initial level of each attribute (H=O=F=V=T=0), and assume that all of the other variables remain constant, we obtain the following WTP estimates by totally differentiating equation (5).

$$\begin{aligned} WTP_H &= dT/dH = -\beta_1/\beta_5 \\ WTP_O &= dT/dO = -\beta_2/\beta_5 \\ WTP_F &= dT/dF = -\beta_3/\beta_5 \\ WTP_V &= dT/dV = -\beta_4/\beta_5 \end{aligned} \qquad \textbf{(7)}$$

The second model that we estimated was a variation of the full quadratic model that also included individual specific, or demographic, characteristics of the respondents. These variables were incorporated by interacting them with the attribute information[5] . In this paper we report results incorporating respondent's age, employment status, income, and experience with cardio-respiratory diseases. This gives us the following form.

[5]Note that any individual-specific characteristic cancel out of equation (4) unless it interacts with the attributes. Greene's (1993) suggestion of multiplying demographic variables by dummy variables for each choice within a set was impractical because separate dummies would have been required for each of the 27 (9x3) distinct alternatives to the status quo faced by each individual. Instead we chose to interact the demographic variables with each level of the attribute.

$$\begin{aligned}\mu = &\beta_1 H + \beta_2 O + \beta_3 F + \beta_4 V + \beta_5 T + \beta_6 (H \cdot O) + \beta_7 (H \cdot V) + \beta_8 (H \cdot T) + \beta_9 (H \cdot F) + \beta_{10} H^2 + \beta_{11} O^2 \\ &+ \beta_{12}(O \cdot V) + \beta_{13}(O \cdot F) + \beta_{14}(O \cdot T) + \beta_{15} V^2 + \beta_{16}(V \cdot F) + \beta_{17}(V \cdot T) + \beta_{18} F^2 + \beta_{19}(F \cdot T) + \beta_{20} T^2 \\ &+ \beta_{21}(I \cdot H) + \beta_{22}(I \cdot 0) + \beta_{23}(I \cdot F) + \beta_{24}(S \cdot V) + \beta_{25}(I \cdot T) + \beta_{26}(E \cdot H) + \beta_{27}(E \cdot O) + \beta_{28}(E \cdot F) \\ &+ \beta_{29}(E \cdot V) + \beta_{30}(E \cdot T) + \beta_{31}(A \cdot H) + \beta_{32}(A \cdot O) + \beta_{33}(A \cdot F) + \beta_{34}(A \cdot V) + \beta_{35}(A \cdot T) + \beta_{36}(C \cdot H) \\ &+ \beta_{37}(C \cdot O) + \beta_{38}(C \cdot F) + \beta_{39}(C \cdot V) + \beta_{40}(C \cdot T)\end{aligned} \qquad \textbf{(8)}$$

Where I = income (in 1000's)
E = employment variable (1 if unemployed, zero otherwise)
A = age (in years)
C = experience with cardio-respiratory disease (1 if the respondent or a household member is currently diagnosed with a cardio-respiratory disease)

Estimating willingness to pay in the same way as in model 1 we obtained the following:

$$\begin{aligned}WTP_H &= dT/dH = -(\beta_1 + \beta_{21} I + \beta_{26} E + \beta_{31} A + \beta_{36} C)/(\beta_5 + \beta_{25} I + \beta_{30} E + \beta_{35} A + \beta_{40} C) \\ WTP_O &= dT/dO = -(\beta_2 + \beta_{22} I + \beta_{27} E + \beta_{32} A + \beta_{37} C)/(\beta_5 + \beta_{25} I + \beta_{30} E + \beta_{35} A + \beta_{40} C) \\ WTP_F &= dT/dF = -(\beta_3 + \beta_{23} I + \beta_{28} E + \beta_{33} A + \beta_{38} C)/(\beta_5 + \beta_{25} I + \beta_{30} E + \beta_{35} A + \beta_{40} C) \\ WTP_V &= dT/dV = -(\beta_4 + \beta_{24} I + \beta_{29} E + \beta_{34} A + \beta_{39} C)/(\beta_5 + \beta_{25} I + \beta_{30} E + \beta_{35} A + \beta_{40} C)\end{aligned} \qquad \textbf{(9)}$$

Note that WTP varies with demographic characteristics in this model. The average value of each of these variables was used in the calculation of WTP.

4. Results

4.1. General Results

The final version of the questionnaire was mailed to 1,908 addresses on February 10, 1997. 246 questionnaires were returned because the addressee had moved and thirteen others were removed from the sample because the recipients had died, were incapable of answering, or had received a misprinted questionnaire. 515 completed surveys (31% of the remaining 1649) were returned by March 19, 1977 (Table 4).

The median age of the sample was 42 years old, which is slightly lower than the median age, of 48, for those over the age of 19 in the entire Regional Municipality of Hamilton-Wentworth (Table 5). The survey sample displayed a higher percentage of those with university degrees (15% vs 10%) and a higher percentage of homeowners (84% vs 62%) than is found in the entire region. There was also lower proportion of low-income households in the survey sample, a higher median income, and a lower rate of unemployment. With respect to the health characteristics of the respondents a higher percentage stated that they suffered from respiratory problems, while a similar proportion stated that they had heart or circulatory problems.

Table 6 presents the results to selected questions from section A of the questionnaire. Air quality in Hamilton-Wentworth is perceived to be poor. The majority of the respondents (58%) thought the air quality in their neighbourhood was somewhat worse or much worse than the rest of Southern Ontario. Only 15% of the respondents thought that air quality in their neighbourhood was better than the rest of Southern Ontario. The majority of the respondents were either very concerned or extremely concerned about each of the four air quality attributes. Respondents were most concerned with health effects, with 81.2% of the respondents reporting they were very concerned or extremely concerned. Concern for the remaining attributes was also high, with 70.4%, 58.0% and 56.0% of respondents reporting they were very concerned or extremely concerned about black fallout, bad odour and poor visibility respectively. Recall that these attributes had not yet been described when the questions about level of concern were posed. As a social issue, air quality ranks slightly below crime, unemployment, and the quality of the educational system, distinctly above the level of taxes, and far above the quality of snow removal. Health effects were ranked first in personal importance by 85% of the respondents, while black fallout, bad odour, and poor visibility were ranked first by 9%, 7%, and 4% of the respondents, respectively (Table 6, Panel D).

Apparently some respondents had difficulty in ranking the choice sets in Section B. In some cases respondents left a choice set entirely unranked, in others they gave only a partial ranking or gave the same ranking to more than one choice. 135 of the 515 respondents committed at least one of these ranking violations. Moreover 240 of 515 respondents violated at least one dominance relationship (see Table 7). However, 83 of this latter group violated only one of the nine dominance relationships, while a further 61 violated only two. The respondents who committed ranking or dominance violation were distinctly older, poorer and less well educated than the remaining respondents (Table 8).

4.2 Willingness to Pay Results

Given the evidence of cognitive difficulties in completing the questionnaire, we decided to conduct model specification tests on the "cleanest" data, that is, the set of 188 respondents who committed neither ranking nor dominance violations. Using only the first ranked choices, we estimated the full quadratic model with and without the demographic variables[6]. We tested and rejected a linear form ($p<0.001$) on a likelihood ratio test) and a linear form augmented by a quadratic term in taxes ($p<0.001$). As a group, the demographic variables were highly significant ($p<0.001$). Consequently we used the results from the full quadratic model with demographics as our reference point for further discussion. Table 9 reports the willingness-to-pay for the four air

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[6]We are aware that due to multiple observations from individuals, there is the possibility that the residuals in the regression model may not be independent. We have not attempted to correct for this problem at the present time.

quality attributes computed for this and other regressions using the formulae developed in section 4 above.

The baseline regression implies that our respondents were willing to pay an additional $39.70 per month in property taxes to achieve a reduction of one third in the adverse health effects of air pollution, that is to reduce excess hospital admissions by 6 to 12 per month and to reduce excess mortality from two deaths to one death per month. They were willing to pay $14.40 per month for a one third improvement in visibility (i.e. from 3 poor visibility days per month to 2 poor visibility days per month), $13.10 per month for a one-third improvement in odour (from 4 to 3 days per month), and $12.80 per month for a one-third improvement in black fallout (from 3 days to 2 days per month). The precision of these estimates is somewhat low, however (see table 9, row 1). The estimated willingnesses-to-pay for odour, black fallout and visibility are all less than their asymptotic standard errors while the willingness-to-pay for health is only slightly greater than twice its asymptotic standard error. Eliminating the demographics from the regression greatly improves the precision of the estimates without substantially altering their magnitude (compare rows 1 and 4 of Table 9).

We tested the sensitivity of these estimates both to the quality of the data and the number of rankings used in the estimation. To address the quality of the data, we estimated the full quadratic model for two larger subsets of our data. As a first step in enlarging the data set, we included all the completely ranked choice sets that were free of dominance violations. Thus even if an individual had committed a dominance violation in one choice set the information from the remaining eight choice sets was used. As a second step we included all the completely ranked choice sets, whether they included a dominance violation or not. Table 9 shows that the willingness-to-pay estimates are indeed sensitive to the quality of the data used. Willingness-to-pay for improved health rises from $39.70 to $66.50 to $173.20 per month as the quality of the data set diminishes. It is important to notice, however, that willingness-to-pay for any attribute is essentially the ratio of the coefficient on that attribute to the coefficient on taxes. The coefficients involving health, odour, black fallout and visibility improvements remain relatively constant across the three data sets. The increase in WTP is primarily due to a reduction in the point estimates of coefficients involving taxes. It is also interesting to note that the precision of the estimated WTP, as indicated by the asymptotic standard errors, falls precipitously when we move to the broadest data set.

We also investigated gains to Chapman and Staelin's procedure for using information from second and subsequent rankings. The second ranked choice is the most preferred of the three alternatives that remain after the first choice is eliminated. Thus we can create a new data matrix from the original by deleting all the rows corresponding to first choices and flagging as most preferred the choices originally ranked second. Combing the new data set with the original effectively doubles the sample size. Similarly, third choices can be considered by deleting the first and second choices and flagging the third choices as most preferred.

Table 9 shows that adding the second-ranked choices is indeed successful in increasing the apparent precision of the estimates. The asymptotic error on willingness-to-pay for health improvements falls from 9.9 to 5.7 in the basic model without demographics and from 19.2 to 15.6 for the basic model with demographics. The asymptotic standard errors on other WTP estimates fall in parallel. However the estimated coefficients on the tax terms fall using this procedure, resulting in higher estimates of willingness to pay for each of the attributes. Extending the procedure to consider the first three choices, however, does not improve the estimates.

Standard errors begin to rise and the point estimates of the tax coefficients fall, resulting in large and less precise estimates of willingness-to-pay.

5. Discussion

Our results are of interest both substantively and methodologically. On substantive issues, the survey demonstrates clear concern about the effects of air quality in the Regional Municipality of Hamilton-Wentworth. Most respondents believe that the air quality in the Region is somewhat worse than the rest of Southern Ontario. Respondents consistently rated health effects as their most serious concern. Black fallout, bad odours, and poor visibility were ranked second, third, and fourth respectively (Table 6). Given the generally perceived hostility to tax increases, it is interesting that respondents generally rated air quality as a more important issue than the level of taxes. Future work will exploit the demographic and geographic detail in the data set to investigate the correlates of these attitudes.

Our preferred estimates of willingness-to-pay for improved air quality attributes run from about $13 per month for one-third improvements in black fallout and odour and $14 per month for one-third improvements in visibility to about $40 per month for reduction in health effects (Table 9). The ranking of attributes by willingness-to-pay is largely consistent with these direct rankings (Table 6) although the estimated willingness-to-pay for improved visibility exceeds willingness-to-pay for improvements in odour and particulate deposition. It is important to note that selection bias may have prevented this sample from being entirely representative of the region of Hamilton-Wentworth. We have already noted that those who successfully completed the ranking task were younger and better educated than the rest of the sample. In addition, those who chose to return the survey may have had particularly strong concerns about of air quality. Both factors may have biased the results. As noted earlier the survey sample was of a higher age, lower income and higher income than the Regional Municipality of Hamilton-Wentworth.

The estimates of willingness-to-pay are indeed quite substantial, but they are not inconsistent with other studies. Loehman *et al.* (1994) estimated WTP for increases in either health or visibility to be about US$13 per month, apparently at 1980 prices[7]. The health effects were not as explicitly defined as they were in the present study, nor was the actual value of the benefits. In an earlier study, Loehman and De (1982) estimated the yearly WTP for a one-day per year reduction in severe cough, severe shortness of breath, and minor eye irritation to be between US$7 and US$46, depending on the income and other factors[8]. Hall *et al*.(1992) combined the results from several contingent valuation as well as other willingness to pay studies to obtain a willingness to pay of US$23 (at 1990 prices) per day for a one-day-per-year reduction in minor-restricted-activity-days. Note that this restriction to personal benefits excludes the public good aspect of air quality which may be captured in our estimates. Note that this was a WTP for a one-day reduction, as well, as opposed to a more substantial reduction. It was also encouraging to find that the estimated willingnesses-to-pay were broadly consistent with what the average taxpayer pays for regional services. Respondents were willing to pay slightly less for a decrease in health risk than they pay for education, and the other estimates fell in line with what was being paid for services such as police, roadways, and waste management.

Our results demonstrate the need to control the quality of data collected in this type of choice experiment. The responses indicate that the ranking task was difficult. A number of

[7]The survey was conducted in 1980. We assume that the values reflect that year's price levels.

[8]It is unclear in which year the survey was conducted.

respondents did not attempt the exercise at all. Others failed to follow the instructions in ranking the choices or chose alternatives that were dominated by others in the choice set. Excluding the respondents who committed dominance violations substantially improved the precision of the estimated willingnesses-to-pay. Excluding these respondents also increased the size and significance of the tax coefficients and led to somewhat lower point estimates of willingness-to-pay. It would be useful to investigate whether the lower significance of the tax coefficient among the groups making ranking errors is due to misunderstanding or a lower sensitivity to increased taxes.

Our conclusions about exploitation of multiple rankings are mixed. It is clear that the precision of the estimates is improved by considering first and second rankings together, however, the critically important tax terms tend towards zero and lose significance under this procedure, inflating the WTP estimates. Asking for a ranking of four choice sets may also increase the cognitive difficulty of answering the questionnaire, leading to a reduced and biased sample. Investigating the trade-off here would be useful. It may be that there are alternative methods for exploiting the ranking data. We intend, for example, to see whether results are significantly different when we use the *least* preferred alternative in the analysis.

Overall, we view the results as encouraging. Choice experiments clearly permit much more detailed valuation of the attributes of environmental services than was previously possible. We have demonstrated that a complex choice experiment can be administered by mail to a representative sample of an urban population, although we suspect we are close to the boundary of what can reasonably accomplished in this manner. More expensive personal interview techniques may yield gains in comprehension, but the sheer magnitude of the rating task will require well motivated respondents.

References

Adamowicz W., J.J. Louvierre , and M. Williams (1994) “Combining Revealed and Stated preference methods for valuing environmental amenities.” *Journal of Environmental Economics and Management*,26:271-92

Burnett R.T., R. Dales, D. Krewski, R.Vincent, T. Dann, and J.R. Brook (1995) “Associations between ambient particulate sulfate and admissions to Ontario hospitals for cardiac and respiratory diseases.” *American Journal of Epidemiology*, 142(1):15-22

Chapman, R.G., and R. Staelin (1982) “Exploiting rank ordered choice set data within the stochastic utility model.” *Journal of Marketing Research*,XIX:282-301

City of Hamilton. (1996) *Current Estimates*

Diamond, Peter D., and Jerry A Hausman (1994) "Contingent valuation: Is some number better than no number?" *Journal of Economic Perspectives* 8(4), 45-66

Dickson L.L., J.D. Heale, and L.W. Chambers (1997) *Fact Book on Health in Hamilton-Wentworth*. McMaster University: Health Priorities Analysis Unit, Faculty of Health Sciences

Dillman DA. (1978) *Mail and Telephone Surveys: The Total Design Method*. New York: John Wiley and Sons

Dockery DW, and C.A. Pope(1994) “Acute respiratory effects of particulate air pollution.” *Annual Review of Public Health*,15:107-32

Elliott S.J., P. Kreuger, D. Cole, R. Hall, N. Voorberg, S. Thorne, and S. Wakefield. (1997) *Perceptions of Air Pollution: The North Hamilton Survey*. Final Report, Prepared for the Hamilton-Wentworth Air Quality Initiative

Greene W.H. (1993) *Econometric Analysis*. Second Edition. New York: Macmillan Publishing Company

Hall J.V., A.M. Winer, M.T. Kleinman, F.W. Lurmann, V. Brajer, and S.D. Colome (1992) “Valuing the health benefits of cleaner air.” *Science*. 255:812-817

Hanemann, W. Michael (1994) "Valuing the Environment through Contingent Valuation" *Journal of Economic Perspectives*, 8(4):19-44

Layton D.F. (1995) *Specifying and Testing Econometric Models for Stated Preference Surveys*. Ph.D. Thesis, University of Washington

Loehman E., and V. De (1982). “Application of stochastic choice modeling to policy analysis of public goods: A case study of air quality improvements.” *The Review of Economics and Statistics* 64:474-480

Loehman E., S. Park ,and D. Boldt (1994). “Willingness to pay for gains and losses in visibility and health.” *Land Economics*. 70(4): 478-498

Louviere J.J. (1988) *Analyzing Decision Making: Metric Conjoint Analysis*. California, USA: Sage Publications

Louviere J.J., and G. Woodworth (1983). “Design and analysis of simulated consumer choice or allocation experiments: An approach based on aggregate data.” *Journal of Marketing Research,* 350-67

Louviere J.J. (1997) “Conjoint Analysis modeling of stated preferences.” *Journal of Transport Economics and Policy,* 22:93-118

McFadden D. (1974) “Conditional logit analysis of qualitative choice behavior”. In Zarembka P, editor. *Frontiers in Econometrics*. New York: Academic Press. 1974; p.105-42

Ministry of Health, Ontario. (1992) The 1990 *Ontario Health Survey*

Mitchell R, Carson RT.(1989) *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Washington, D.C. Resources for the Future

Petersen, R.G. (1985) *Design and Analysis of Experiments*. New York: Dekker

Portney, Paul R. (1994) The contingent valuation debate: Why economists should care" *Journal of Economic Perspectives* 8(4), 3-18

Rowe R.D., R. D’Arge, and S. Brookshire(1980). “An experiment on the economic value of visibility.” *Journal of Environmental Economics and Management,* 7:1-19

Ryan Mandy, Anthony Scott, Shelly Farrar, Phil Shackley, Sandra Vick, and Emma McIntosh (1996) Using conjoint analysis in health care: unresolved methodological issues. *HERU Discussion Paper* 2/96 Health Economics Research Unit, University of Aberdeen, Aberdeen, Scotland

Schulze W., G. McClelland, M. Doane, E. Balistreri, R. Boyce, B. Hurd, and R. Simenauer (1995) *An Analysis of Stated Preferences for Superfund Site Cleanup*. Department of Agricultural, Resource, and Managerial Economics, Cornell University, unpublished paper.

Shechter M., and M. Kim (1989). “Valuation of pollution abatement benefits: Direct and indirect measurement.” *Journal of Urban Economics,* 30:133-151

Shechter M (1991). “A comparative study of environmental amenity valuations.” *Environmental and Resource Economics*, 1:129-155

The Regional Municipality of Hamilton-Wentworth (1996). *1996 Budget*

Table 1: Levels of the attributes employed

Attribute	Current Situation	About One-third Better	About One-third Worse
Bad Odour	**4** days of bad odour per month	**3** days of bad odour per month	**5** days of bad odour per month
Black Fallout (BFO)	**3** days of black fallout per month	**2** days of black fallout per month	**4** days of black fallout per month
Visibility	**3** days of poor visibility per month	**2** days of poor visibility per month	**4** days of poor visibility per month
Health Effects	**18** extra hospital admissions per month and **2** extra deaths per month, compared to perfectly clean air	**12** extra hospital admissions per month & **1** extra death per month, compared to perfectly clean air	**24** extra hospital admissions per month and **3** extra deaths per month, compared to perfectly clean air

Table 2: Estimation of Cardio-Respiratory Hospital admissions

Disease and associated ICD9* codes	Hospital discharges of Hamilton-Wentworth residents (1990)
cardiac:	
all ischemic, 410-414	3107
all other heart disease 390-398, 415-429..	1951
total cardiac	5108
respiratory:	
pneumonia, 480-486	961
copd, 491-496	978
asthma, 493	468
total respiratory	2407

*International Classification of Diseases, Ninth Revision
source: Dickson *et al.*, 1995

Table 3: Increase or Decrease in Property Tax by Choice Set and Version

	Version					
Choice Set	A	B	C	D	E	F
1 (Q23)	$50	$5	$10	$15	$20	$25
2 (Q24)	$15	$20	$25	$50	$5	$10
3 (Q25)	$5	$10	$15	$20	$25	$50
4 (Q26)	$20	$25	$50	$5	$10	$15
5 (Q27)	$5	$10	$15	$20	$25	$50
6 (Q28)	$25	$50	$5	$10	$15	$20
7 (Q29)	$10	$15	$20	$25	$50	$5
8 (Q30)	$10	$15	$20	$25	$50	$5
9 (Q31)	$15	$20	$25	$50	$5	$10

The amount shown is the size of the property tax increase or decrease specified in each case. For example, question 23 of version B (shown in this appendix) contains either an increase or decrease of $5 as the tax change.

Table 4: Response Statistics

Total questionnaires mailed	1908	
Removed from sample:		
returned undelivered/moved	246	
deceased	7	
incapable	5	
misprint	1	
Total removed from sample:	259	
Sample remaining	1649	
returned completed	515	
response rate:	31%	(515/1649)

notes:
-deceased: these were either returned unopened and marked as deceased, or phoned in by a relative after receiving the postcard
-incapable: blind, mentally challenged or elderly, as informed by a relative via letter or phone call
-some of the non-respondents may also belong to one of the above groups.

Table 5: Sample Characteristics, Survey Sample vs Region of Hamilton-Wentworth[a]

Characteristic	survey sample	Hamilton-Wentworth
percentage female	54	51[d]
percentage with university degree	15	10[d]
percentage low income households (<$30,000 per year)	28	36[d]
median income[g]	$43,550	$41,213
percentage homeowners	84	62[d]
median age[g]	48	42[d,f]
percentage unemployed	3	7[d,h]
percentage with respiratory problems[b]	11	7[e]
percentage with heart or circulatory problems[c]	6	6[e]

[a] Note that some of the census data and all of the OHS data is based on a sample of the entire Region of Hamilton-Wentworth
[b] Defined as asthma. emphysema, chronic bronchitis, or persistent cough. In the survey persistent cough was not included
[c] Defined as "heart disease" in the survey, "Circulatory and heart disease" in the Ontario Health Survey
[d] Source: 1991 Census
[e] Source: 1990 Ontario Health Survey
[f] median age of the population over the age of 19 in Hamilton-Wentworth
[g] estimated by assuming a uniform distribution within each income and age category
[f] estimated based on the unemployment rate for the Hamilton CMA in December,1996

Table 6: Responses to Selected Questions in Section A** (in percentages)

A) How would you describe the air quality in your neighbourhood compared to the rest of southern Ontario? (question 1)

N*	Much better than the rest of Southern Ontario	Somewhat better than the rest of Southern Ontario	The same as the rest of Southern Ontario	Somewhat worse than the rest of Southern Ontario	Much worse than the rest of Southern Ontario	Don't Know
508	2.5	12.8	18.8	41.5	16.9	6.0

B) How concerned are you about annoying odours/black fallout/poor visibility/health effects of air pollution in Hamilton-Wentworth? (questions 2-5)

	N*	Not at all concerned	A little concerned	somewhat concerned	very concerned	extremely concerned	don't know
annoying odours	511	4.3	11.8	25.0	36.0	22	0.4
black fallout	511	4.1	7.0	15.7	34.5	35.9	2.0
poor visibility	511	5.2	12.2	24.0	34.0	22.0	1.6
health effects	512	1.0	4.8	11.4	31.8	50.0	0.2

C) Do you think that the issue is a more serious issue, a less serious issue, or about as serious an issue as air quality (Questions 6-10)

Issue	N*	more serious issue	less serious issue	equally as serious an issue
the level of crime	509	32.4	11.2	55.0
the level of taxes	504	17.7	40.3	39.5
snow clearing	504	8.5	53.1	36.1
quality of educational system	505	28.3	16.3	53.3
level of unemployment	507	27.9	20.5	49.8

D) Which attribute is the most important to you?(Question 21)

	percentage	average

Bad Odour	7.2%	2.8
Black Fallout	8.9%	2.7
Poor Visibility	4.0%	3.1
Health Effects	85.1%	1.2

*some respondents did not answer all of the questions or may have recorded multiple responses and were excluded from these statistics

Table 7: Distribution of Questionnaires with Dominance and Ranking Violations

	ranking violation	no ranking violation	total
dominance violation	48	192	240
no dominance violation	87	188	275
total	135	380	515

Table 8: Selected Demographic Characteristics by Ranking Violations

	entire sample (N=515[a])	no ranking or dominance violations (N=188[a])	one or more ranking or dominance violations (N=327[a])
median age	48	45	52
median income[b]	$43,550	$51,600	$31,300
percentage low-income households (<$30,000)	28	14	36
percentage unemployed	3.48	2.78	3.88
percentage with university degree	15	21	12

[a] note: Not all of the respondents answered all of the questions
[b] estimated by assuming a uniform distribution within each income category

Table 9: WTP for a One-third Improvement in Air Quality by Statistical Model and Number of Rankings Employed, in Dollars per Month (Asymptotic Standard Errors in Parentheses)

sample employed*	model	rankings used	health	bfo	odour	visibility	pseudo R^2
Respondents with no violations	full quadratic plus demographics (N=1332)	1st choices	39.7 (19.2)	12.8 (18.4)	13.1 (15.9)	14.4 (15.9)	.6141
		1st and 2nd choices	51.1 (15.6)	15.3 (14.1)	13.0 (11.9)	14.5 (12.6)	.5063
		1st,2nd & 3rd choices	83.9 (23.9)	22.2 (18.5)	24.2 (15.8)	23.0 (16.0)	.4445
	full quadratic (N=1692)	1st choices	40.2 (9.2)	13.3 (4.2)	12.3 (4.7)	13.8 (4.7)	.6202
		1st and 2nd choices	55.7 (5.7)	16.3 (2.3)	14.9 (2.6)	19.0 (2.7)	.5138
		1st,2nd & 3rd choices	83.9 (8.2)	21.5 (2.4)	24.3 (3.0)	26.4 (3.1)	.4515
All choice sets with complete ranking, excluding those with dominance violations	full quadratic plus demographics (N=2756)	1st choices	66.5 (22.5)	22.5 (20.0)	18.5 (17.7)	27.9 (19.0)	.4947
		1st and 2nd choices	77.7 (17.6)	25.9 (15.2)	20.4 (13.6)	23.6 (14.3)	.3650
		1st,2nd & 3rd choices	118.0 (25.7)	37.9 (19.3)	32.8 (17.4)	31.4 (17.4)	.3013
	full quadratic (N=3344)	1st choices	63.9 (11.6)	20.8 (4.9)	19.3 (5.4)	26.9 (5.9)	.4984
		1st and 2nd choices	77.0 (7.5)	24.9 (3.0)	21.2 (3.2)	25.4 (3.2)	.3680
		1st,2nd & 3rd choices	115.7 (12.6)	36.3 (4.1)	32.9 (4.3)	30.3 (3.9)	.3044
All choice sets with complete ranking.	full quadratic plus demographics (N= 3155)	1st choices	159.3 (62.2)	57.7 (43.9)	67.0 (42.6)	52.1 (40.0)	.4377
		1st and 2nd choices	148.1 (37.4)	47.2 (28.2)	51.2 (26.3)	43.8 (25.8)	.3035
		1st,2nd & 3rd choices	183.2 (47.8)	52.8 (31.6)	57.2 (29.1)	57.0 (29.0)	.2471
	full quadratic (N=3798)	1st choices	173.2 (55.3)	62.7 (20.7)	79.4 (27.0)	60.0 (21.7)	.4382
		1st and 2nd choices	146.5 (22.6)	45.2 (7.3)	52.1 (9.1)	46.5 (8.4)	.3001
		1st,2nd & 3rd choices	175.4 (28.9)	49.1 (8.0)	55.2 (9.8)	51.2 (9.4)	.2456

*N refers to total number of choice sets included in the regressions of the first choices. Note that not all respondents answered all of the demographic questions, thus the regressions that included demographics included less observations than the regressions that did not include the demographics

Figure 1

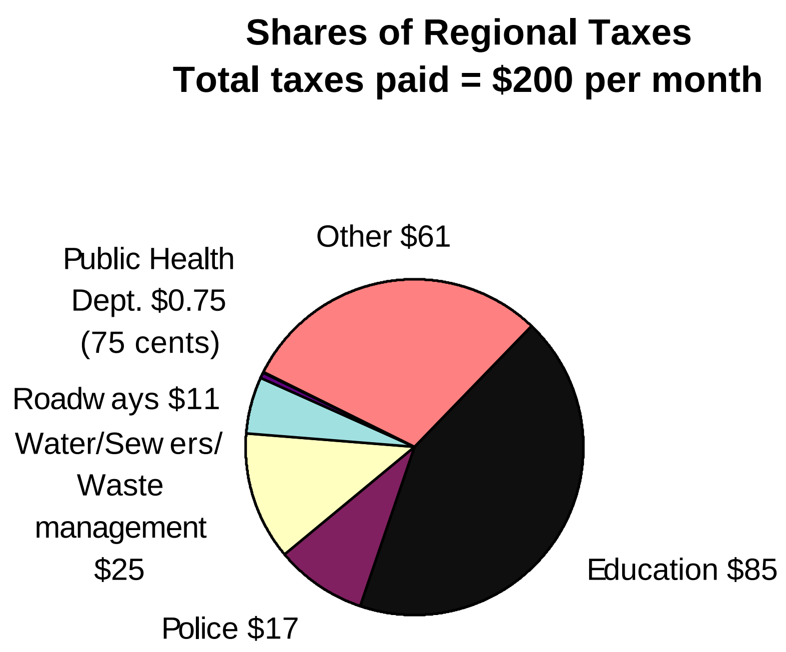

Figure 2: Sample Question Taken from the Questionnaire

	State of the Environment			
Attribute	Choice A (Current situation*)*	Choice B	Choice C	Choice D
Bad Odour	4 days of bad odour per month	One-third Worse	One-third Better	Same
Black Fallout (BFO*)*	3 days of BFO per month	One-third Worse	One-third Better	Same
Poor Visibility	3 days of poor visibility per month	One-third Worse	One-third Better	Same
Health Effects	18 extra hospital admissions per month and 2 extra deaths per month, compared to perfectly clean air	One-third Worse	One-third Better	Same
Monthly Property Taxes or Rent	$200 per month for typical household	$5 more taxes/rent	$5 less taxes/rent	$5 more taxes/rent
Rank	***2***	***4***	***1***	***3***

Please put a 1 under the choice you like BEST.
Please put a 4 under the choice you like LEAST.
Consider the remaining choices. Put a 2 under the one you like best. Put a 3 under the other one.

A Sample Question

Suppose that you like choice C the best. You would put a 1 under choice C as shown.
Suppose that you like choice B the least. You would put a 4 under choice B as shown.
Choice A and D remain. Suppose you like Choice A better than Choice D. You would put a 2 under that Choice A and a 3 under Choice D, as shown.