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Using willingness-to-pay to assess the economic value of weather forecasts for multiple commercial sectors

Kimberly S. Rollins[1] & Joseph Shaykewich[2]
[1] *Department of Applied Economics and Statistics, Mail Stop 204, University of Nevada, Reno NV 89557, USA*
[2] *Meteorological Services of Canada, Downsview, Ontario*
Email: krollins@cabnr.unr.edu

This paper uses an alternative to the usual cost-avoidance approach to estimating the value of weather forecast products. Value is estimated via a demand-based approach based on the willingness to pay of those who use weather forecast services. Contingent valuation is used to estimate the benefits generated by an automated telephone-answering device that provides weather forecast information to commercial users in the Toronto area of Ontario, Canada. Commercial sectors included in the study are construction, landscaping/snow-removal businesses, TV and film, recreation and sports, agriculture, hotel and catering, and institutions such as schools and hospitals. Average value per call varied by commercial sector, from $2.17 for agricultural users to $0.60 per call for institutional users, with an overall mean of $1.20 per call. At roughly 13,750,000 commercial calls annually, this would result in an estimate of benefits generated by the service to commercial users of $16,500,000 per year.

1. Introduction

A variety of circumstances require economic valuation of meteorological services. Government sponsored meteorological service providers must often justify their activities in terms of their benefits to society. Decisions to offer new services or to change existing services can be supported on the basis of the benefits that the changes are predicted to produce, relative to the costs. Due to the mixed public-private nature of some types of meteorological information services, government agencies may consider implementing user fees for government services, or providing public support to enhance private sector services. Information that is important in determining the appropriate fee structures in these cases include measures of the value of the services to consumers, the degree to which users substitute between available means to acquire the information they desire, and how flexible the demand for a new service is relative to its cost.

The values of meteorological services are often not well understood because many are not estimable using standard methods commonly applied to private market commodities. Anaman *et al.* (1995) describe meteorological services as having the public good characteristics of non-rivalry and non-exclusivity. As others have described elsewhere, goods and services that have these characteristics require specialised non-market economic valuation methods (Freeman 1993; Mitchell & Carson 1990; Perman *et al.* 1999). Standard economic approaches that rely on market data to value changes in these goods and services are not appropriate. However, economists have developed methods for valuing the change in benefits that result from changes in policies that alter the quality and/or quantity of public goods and services that are not traded in markets. These methods have been applied over the past decades to estimate costs and benefits of policy changes affecting numerous public goods and services (Kopp *et al.* 1997). Economists have found that, while there still is room for continued research into the refinement of these methods, the resulting valuation estimates provide reasonable and theoretically consistent starting points in evaluating the desirability of proposed policy changes that would affect public good provision. Kopp *et al.* (1997) provide a thorough review of the contingent valuation method, in particular, in the context of public policy evaluation. These methods and the underlying theory are consistent with the problem of measuring changes in benefits to the public that result from changes in meteorological services.

The purpose of this paper is to describe the application of the contingent valuation method to calculate the economic value of an Automated Telephone Answering Device (ATAD) offered by the Meteorological Services of Canada. The WeatherLine provides up-to-date weather information to the general public. The study estimates the economic value of the

ATAD to its commercial users, determines how values differ among different user groups, and uses the economic model to predict how the numbers of users of the service would change in response to different fee structures.

Approximately 55 million calls per year across Canada are placed to the WeatherLine service. About 25% of these calls are by commercial businesses. Before this study was conducted, not much was known about these commercial callers, how they used the information, their available substitutes, or the value of the service to their businesses.

2. Economic valuation of meteorological services

National meteorological service providers around the world have expressed a general interest in the value of weather information services by national meteorological service providers. Herdan & Otten (1994) examine the development of commercial applications of weather forecasts for revenue generation and for increased productivity. Farrow (1994) investigates public and private sector cooperation to offer 'premium' weather information services. Other studies measure the economic value of weather forecasts (Katz & Murphy 1997) to justify the public costs of improving forecast accuracy (Kite-Powell & Solow 1994; Maunder 1970; Anaman *et al.* 1995). Several studies have attempted to measure the value of weather information for commercial users. Many studies have focused on specific industries, including agriculture (Lave 1963; Baquet *et al.* 1976; Tice & Clouser 1982; Bosch & Eidman 1987; Mjelde *et al.* 1988; Babcock 1990; Kite-Powell & Solow 1994; Smith 1994; Anaman & Lellyett 1996a, 1996b; Mjelde *et al.* 1998; Solow *et al.* 1998), aviation (Leigh 1995), highway maintenance (Ackerman 1994), and forest fire prevention (Sol 1994). The majority of past studies have used cost avoidance as a measure of the value of forecasts. Very limited used has been made of demand-based approaches, which are widely used in most other applications when valuing public goods and services.

Cost avoidance methods value marginal changes in the quality (or accuracy) of forecast information indirectly, by modelling them as inputs to specific production processes. The value of a given change in forecast accuracy is measured as the associated change in the market value of the output commodity that is produced. This approach requires specific models of how forecast information affects particular production processes. Weather information is typically modelled as reducing the variance of a stochastic term in the production relationship, caused by an inability to predict events that affect productivity of other inputs. The value of a change in the accuracy of a weather forecast is estimated as equal to the costs that might occur from variations in states of nature. Since cost-averting behaviour and substitutes for inputs are generally not modelled, values estimated as costs avoided tend to be biased upwards, representing an upper bound to the true values. The estimated values are highly specific to the particular production processes as they are modelled. It is often assumed that a change in the input would not alter the structure of the production process or the price of the final good, which limits the extension of the resulting estimates.

Demand-based valuation methods directly value meteorological services in terms of the demand for those services. Specifically, value is estimated using respondents' stated changes in consumption levels in response to proposed changes in the quality or price of service. Rather than modelling the production process, demand-based methods assume that consumers of the services (which may be commercial producers who use the services as inputs) know the maximum amounts that they would be willing to pay (WTP) for specific information services, and that they know the most efficient means of altering their production technology in response to changes in prices or quality of the service. Whereas cost-avoidance methods are particular to specific industries and production process, demand-based methods are applicable in situations where the same service is offered to a cross-section of different users.

Potential biases from using WTP estimates might occur if respondents perceive that understating their actual WTP may lead to avoiding additional costs, or that overstating WTP would lead to better services. Avoidance of such biases is a methodological issue that has received much attention in the economic literature. Incentive-compatible question design to reduce incentives to respond untruthfully and careful pre-testing have been shown to identify and minimise distortions from respondent bias. Respondent bias and other methodological issues beyond the scope of this paper have been the subject of a vast economic literature spanning several decades (Kopp *et al.* 1997). The result is that demand-based methods are widely accepted by economists and policy-makers for goods and services that are not traded in markets and exhibit public goods characteristics.

The choice of valuation method depends upon the policy needs and the nature of the specific good or service. The industry-specific nature of cost avoidance methods makes them most appropriate in cases where decisions must be made regarding how small changes in accuracy of weather information affect the costs of producing specific commodities. The information can also be used for the development of new services targeted at a specific industry. Demand-based methods can be used to inform decisions about allocating priorities for servicing a variety of different user groups, for pricing of a given service, or to determine the value of services for cost-benefit analysis. A demand-based method was selected for the WeatherLine study since a goal was to determine the value of the ATAD service over all its commercial users, rather than for a particular industry, and to determine how the values differed by user group.

3. The contingent valuation method

Contingent Valuation (CV) is a demand-based method widely used to determine economic values for non-marketed goods and services (Mitchell & Carson 1990; Kopp *et al.* 1997). Market prices derive from the interaction of consumer demand and supply. CV relies on the creation of hypothetical market-like scenarios in which the non-market good or service could be provided to generate experimental contexts that provide data that are used to estimate benefits (Bishop *et al.* 1995). The relevant population is sampled and survey instruments based on the hypothesised markets are used to obtain data that in turn is used in models that predict the maximum amounts people would be willing to pay (WTP) to receive a specific level or quality of service, contingent on the market scenario proposed. A feature of well-designed CV studies is that respondents are rarely asked to value explicitly the good in question, rather, the experimental design alters characteristics of the good, including the price, and respondents are asked whether or not they would purchase the good at a given price. This notion of a take-it-or-leave-it response to a given price for a well-defined service is consistent with market experiences of most respondents (Mitchell & Carson 1990) Economic values measured by CV methods are theoretically consistent with economic benefits measures that arise from market data.

The CV questionnaire for this study was designed to take into account the substitutes available for the WeatherLine ATAD service, as well as to determine characteristics of commercial users, the types of business decisions made with the ATAD information, average numbers of calls per week made by commercial sector, and the benefit per call for each sector. A specific goal was to determine how the total number of calls per week could be expected to change with different prices for the service, by commercial sector. At the time of the study, calls to WeatherLine were free of charge to all users.

3.1 The double-bounded dichotomous choice model

The questionnaire used a double-bounded dichotomous choice referendum format, presenting two sets of ‘yes’ or ‘no’ questions to respondents. The term dichotomous choice refers to the binary nature of the response to each question, and the term double-bounded refers to the use of two sets of questions to result in categories of responses that provide upper and lower boundaries to WTP estimates. The term referendum format refers to the use of a hypothetical ‘yes’ or ‘no’ vote to elicit respondents’ preferences for a proposed policy change. The referendum format is widely accepted as a preferred format because it has been shown to be incentive compatible, thus limiting incentives for respondents to give biased answers.

Hanemann (1984) and Carson (1985) initially developed the double-bounded dichotomous choice technique with a number of subsequent refinements (see, for example, Cameron 1988; Cameron & Quiggin 1994; Alberini, Kanninen & Carson 1997). It is widely accepted that the WTP estimates generated through the double-bounded methods are statistically more efficient than those calculated with simpler single-bounded methods (asking only one binary response question), thereby providing more reliable statistical models for hypothesis testing (Haneman *et al.* 1991; Kanninen 1993; and Alberini 1995).

Each respondent was asked how they would vote for a hypothetical proposal that would guarantee that the WeatherLine would be continued at its existing levels of services, contingent on a fee per call basis. A majority ‘yes’ vote would result in the service being retained via a 1–(900) number. A majority ‘no’ vote would result in the service being discontinued. Respondents are told to assume that if a majority voted ‘yes’, the proposal would be accepted and they must pay for the proposed change, even if they voted ‘no’. If the majority voted ‘no’, but the respondent voted ‘yes’, the proposal would not be accepted and the service would be discontinued. The respondents were asked about their expected responses to two different fee levels, with the second amount conditional on their response to the first. We can denote the probabilities of a ‘no’ and ‘yes’ response to the first question as:

$$\pi^n(B) = G(B;\theta)$$

$$\pi^y(B) = 1 - G(B;\theta)$$

where π^n is the probability of a ‘no’ and π^y is the probability of a ‘yes’ and $G(B;\theta)$ is a statistical distribution with parameter vector θ.

Those who responded ‘no’ to the first question were given a second question with a lower dollar amount. Those who answered ’yes’ to the first question were given a higher dollar amount in the second question. We can denote the initial dollar offer amount as B^S and the follow up dollar amounts as B^L and B^U, where $B^L < B^S < B^U$. Over a sample wherein the dollar amounts B^L, B^S, B^U vary across individuals, the resulting sets of responses fall into four categories, based on the first response and the second, conditional response, as shown in Table 1. The conditional probabilities of each of the four response categories for a given respondent *i* are given in equations [1] through [4].

$\pi^{yy}(B^S, B^U)$ = Prob $\{B_i^U \leq \text{max WTP} \leq \text{Income}\}$ = $1 - G(B_i^U;\theta)$ [1]

$\pi^{yn}(B^S, B^U)$ = Prob $\{B_i^S \leq \text{max WTP} \leq B_i^u\}$ = $G(B_i^u; \theta) - G(B_i^S; \theta)$ [2]

$\pi^{ny}(B^S, B^L)$ = Prob $\{B_i^S \geq \text{max WTP} \geq B_i^L\}$ = $G(B_i^S; \theta) - G(B_i^L; \theta)$ [3]

$\pi^{nn}(B^S, B^L)$ = Prob $\{B_i^S \geq B_i^L \geq \text{max WTP}\}$ = $G(B_i^L; \theta)$ [4]

Table 1. *Four categories of responses to double-bounded dichotomous choice questions*

Conditional probability	First response	Second response (conditional on 1st response)
π^{yy}	Yes	Yes
π^{yn}	Yes	No
π^{ny}	No	Yes
π^{nn}	No	No

Equations [1] through [4] indicate that the efficiency from the double-bounded model arises from its ability to place upper and lower boundaries on the respondents' unobserved WTP. Note that in the case of two 'yes' responses, the upper bound of WTP is income.

The distribution G(B;θ) over a continuous range of dollar amounts is typically assumed to be log-logistic. Since a 'yes' response to a given fee amount, B, can be assumed to indicate a 'yes' response to any lower B, then G(B;θ) can be interpreted as a cumulative density function with bounds that range from B = 0 to B = + ∞, as shown in Figure 1. The parameters for this distribution can be estimated using a logit model:

$$\Pr(yes) = \frac{1}{1+e^{-(\beta_o+\beta_i B_i)}} \quad [5]$$

in which Pr (yes) is the probability of a 'yes' response to a given dollar amount B, β_o is an intercept term and β_i is a vector of coefficients on the fee amount and other explanatory variables, such as income. (Note: The probability of a 'no' response is: .)

$$P^n = 1 - P^y = \Pr(no) = 1 - \frac{1}{1+e^{-(\alpha+\beta B_i)}} = \frac{e^{-(\alpha+\beta B_i)}}{1+e^{-(\alpha+\beta B_i)}}.)$$

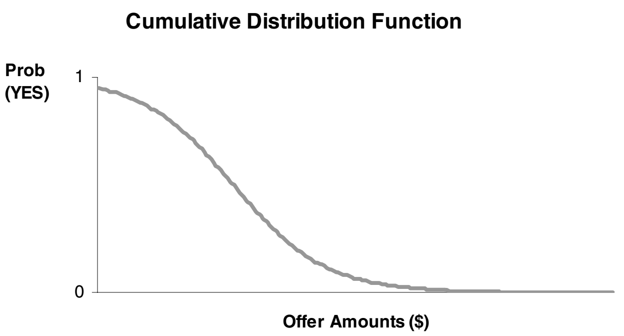

Figure 1. *The cumulative distribution function*

Following Hanneman (1984), the corresponding set of conditional probabilities for a logit specification of the double-bounded model is given in equations [6] through [9].

$$\pi^{YY} = \frac{1}{(1+\exp(-\beta_0 - \beta_1 * B^U - \beta_2 * income))} \quad [6]$$

$$\pi^{YN} = \frac{\exp(-\beta_0 - \beta_1 * B^U - \beta_2 * income)}{(1+\exp(-\beta_0 - \beta_1 * B^U - \beta_2 * income))} - \frac{1}{(1+\exp(\beta_0 + \beta_1 * B^S + \beta_2 * income))} \quad [7]$$

$$\pi^{NY} = \frac{1}{(1+\exp(\beta_0 + \beta_1 * B^S + \beta_2 * income))} - \frac{1}{(1+\exp(\beta_0 + \beta_1 * B^L + \beta_2 * income))} \quad [8]$$

$$\pi^{NN} = \frac{1}{(1+\exp(\beta_0 + \beta_1 * B^L + \beta_2 * income))} \quad [9]$$

Accordingly, the log-likelihood function for the model is written as:

$$\ln L(\theta) = \sum_{i=1}^{N} \begin{bmatrix} d_i^{YY} \ln \pi^{YY}(B^S i, B_i^U;\theta) + d_i^{YN} \ln \pi^{YN}(B^S i, B_i^U;\theta) \\ +d_i^{NY} \ln \pi^{NY}(B^L i, B_i^S;\theta) + d_i^{NN} \ln \pi^{NN}(B^S i, B_i^L;\theta) \end{bmatrix} \quad [10]$$

where $d_i = 1$ if the respondent answers 'yes' and $d_i = 0$ if the response is 'no'. The maximum likelihood estimator for the double-bounded model is the solution, θ, to the equation

$$\frac{\partial \ln L}{\partial \theta} = 0 \quad [11]$$

The mean and median WTP can be calculated from the estimated parameters of the distribution. The median WTP is the dollar amount associated with a 50% probability of a 'yes' and the mean WTP is calculated as the integral of the cumulative density function over the range B = \$0 to B = a high dollar amount that captures 99% or more of the area. The upper level is the asymptotic amount that is approached as the probability of a 'yes' approaches zero. The calculation for WTP is for a representative individual. The mean WTP can then be aggregated over the relevant population of business callers for an estimate of the aggregate value of the WeatherLine ATAD service.

Since WTP estimates are calculated from parameter estimates, a maximum likelihood estimation does not directly provide standard errors for WTP. Therefore, bootstrapping methods are typically used to estimate confidence intervals around WTP estimates (Krinsky & Robb 1986). Thorough explanations of these methods are given in Hanemann & Kanninen (1996) and in Cooper (1993).

4. Results

Extensive pre-testing and pilot surveys were conducted to develop the questionnaire wording and to determine the first- and second-level distributions for dollar amounts. The pre-test sample was drawn from a list of past WeatherLine commercial users who had previously agreed to assist in marketing research activities. A research associate phoned the pre-test volunteers, administered the questionnaire, and then debriefed respondents, asking them to comment on wording, length and ease of understanding. Initially, the first several dozen respondents were asked, in an open-ended fashion, to give the maximum dollar amounts that they would pay for the WeatherLine service. From the initial responses, a wide distribution of WTP bid values was developed and subsequent bid amounts for 'yes' or 'no' responses were drawn from this distribution. As the pre-testing progressed, the range of bid amounts was narrowed so that the final distribution of suggested WTP amounts straddled the median dollar value from the pre-test sample. By selecting offer amounts clustered about the median, the standard errors of the parameter estimates are reduced, thereby increasing the accuracy of the resulting estimates of WTP (Cooper 1993; Alberini 1995; Rollins *et al.* 1997).

The resulting questionnaire, with refined wording and bid design, was administered as a pilot version by intercepting a random sample of calls to the WeatherLine. Final adjustments to the wording and bid amounts were made on the basis of the pilot. The Angus Reid Group, a professional phone survey firm, conducted the interviews for the finalised survey, by intercepting calls to the WeatherLine. A total of 1,300 calls to the WeatherLine service were intercepted, with 1,117 callers agreeing to participate in the survey – an 85% response rate.

The first fee per call dollar amount presented to each individual in the final version of the survey was drawn from \$1.00, \$2.00 or \$3.00, randomly distributed over all respondents such that 40% of respondents received \$1.00, 40% received \$2.00 and 20% received \$3.00. Given an individual respondent's answer to the first question, the respondent was asked whether she/he would continue to use the service if the fee was set at a higher or lower amount, randomly drawn from the amounts: \$0.50, \$1.00, \$2.00, \$3.00, \$4.00, deleting those amounts that were too high or too low. The regression was run with dummy variables representing each commercial sector. WTP estimates for each commercial sector were calculated using the above procedure for the relevant sub-samples.

Regression results and WTP estimates are summarised in Table 2 and Figure 2. The point estimate of the mean WTP for all 1,117 usable cases is \$1.20, bounded by a 95% confidence interval of (1.10 to 1.30). Four commercial sectors have mean WTPs that fall outside the 95% confidence interval for the sample: the television and film industry, the institutional services sector, hotel and catering businesses, and agriculture. Table 2 shows that the television and film industry and the agricultural sector have significantly higher WTPs than the entire sample, with t-statistics on dummy variables for these sectors of t = 2.465, and t = 6.064, respectively. The institutional sector and the hotel and catering sector have significantly lower WTPs than the entire sample, with t-statistics of t = –2.764, t = –2.062. The agricultural sector, with a sample size of 86, has an estimated mean WTP of \$2.17. The television and film industry, with a sample size 72, has an estimated mean WTP of \$1.59.

The institutional sector, which included 44 schools and hospitals, has an estimated mean WTP of \$0.60. While this point estimate is significantly below that of the entire sample, it should be noted that the upper confidence limit is above that of the entire sample. The hotel and catering sector, with sample size 48, has an estimated mean WTP of \$0.66, but the confidence interval falls below that of the entire sample. The large width of the confidence intervals illustrated in Figure 2 is partly a result of the small sample sizes, and partly a result of the diversity within sectors.

5. Policy implications

Based on the survey sample, the annual gross revenue of 43% of the commercial callers to the WeatherLine is

Table 2. *CVM results for WeatherLine callers*

Group	Size N	t-Statistic on sector dummy	Log Likelihood	WTP Point Estimate	Lower C.I. (95%)	Upper C.I. (95%)
Entire Sample	1117	N/A	–1248.4082	1.20	1.10	1.30
Institutional	44	–2.764	–30.7816	0.60	0.32	1.53
Hotel/Catering	48	–2.062	–43.6111	0.60	0.43	1.11
Other	457	N/A	–480.6490	1.06	0.91	1.24
Construction	199	–0.285	–221.0267	1.17	0.95	1.41
Landscape/Snow	116	0.684	–135.6974	1.23	0.98	1.61
Recreation/Sport	95	0.209	–96.2366	1.38	0.98	2.10
TV/Film	72	2.465	–89.7667	1.59	1.24	2.11
Agriculture	86	–6.064	–1113.2737	2.17	1.81	2.59

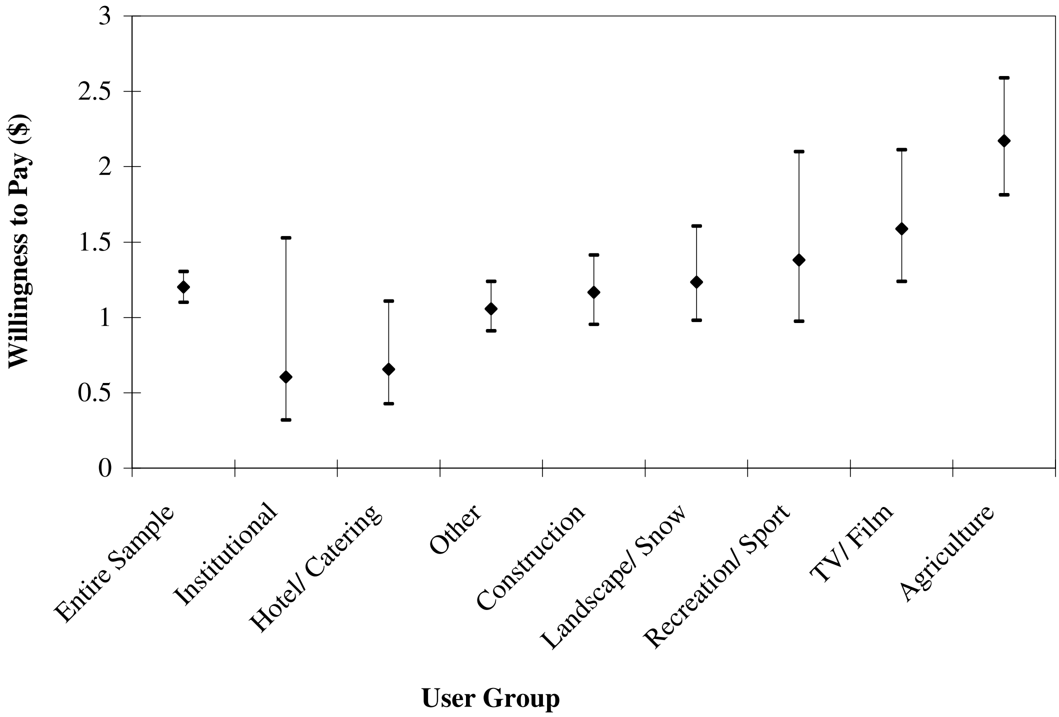

Figure 2. *WTP by commercial sector and 95% confidence intervals*

less than $500,000. The average business establishment in the sample calls the WeatherLine once a day (five to seven times a week) and the mean willingness to pay of businesses on a per call basis is around $1.20 per call. Across Canada, approximately 55 million calls are currently placed each year to the WeatherLine ATAD system at a fee of $0 per call. The percentage of calls from commercial establishments is generally accepted as 25%, on average, across regions. This translates to about 13,750,000 commercial calls annually. This would result in estimated gross benefits of $16,500,000 per year generated by the service to commercial users, at its current level of service.

The results of this study indicate that the WeatherLine may provide a source of revenue generation that would at least cover the cost of the ATAD service and potentially help to cover the costs of basic programs that generate forecasts. However, the resulting mean WTP of $1.20 per call over all commercial sectors does not mean that charging this amount would generate the revenues equal to 1.20 times the current use rate of 13,750,000. Rather, this amount indicates the average surplus benefits received by current users who currently pay no fee at all. Multiplying $1.20 per call by the total number of calls placed provides an estimate of the gross aggregate social benefits generated by the current free service, where the average per call benefit is $1.20. Because $1.20 is the mean value, anyone with a per call value below $1.20 would no longer use the service, and these fees would not be collected. Thus, revenues generated may be less than the aggregate benefits of the current service.

5.1 Estimating revenue generating potential

Drop-off percentages (elasticities of demand) were calculated based on the distribution of 'no' responses, in order to determine the revenue-generating capacity of a fee per call WeatherLine system. The drop-off rate is the percentage of calls lost if a specific dollar amount were to be charged for WeatherLine calls. Since not every caller was offered every dollar amount, these are probabilistic estimates, based on the distribution parameters generated by the entire sample.

Respondents who answered 'yes' to WTP questions were asked whether they would call *less often* if they were charged per call. Those who said they would call less often were asked to indicate how many calls per week they would make if the suggested fee were charged. The number of calls lost and percentages drop-offs were calculated for each fee level.

The total number of calls resulting from each of the given fee amounts was tallied, as were the number of calls each respondent said that their business currently placed to the WeatherLine each week. This number of calls is C_T, total number of calls made for $0 per call. Similarly, the total number of respondents who said 'no' to each of the given fee amounts was tallied, as were the number of calls they placed each week. This number of calls is C_N, the number of calls lost due to refusal to pay. The total number of callers who said 'yes' to a given fee amount and who also said 'yes', that paying that fee per call would cause them to decrease the number of calls they made per week, were tallied along with the number of calls they placed each week.

Table 3. *Drop-off percentages according to dollar amount*

Dollar amount offered	Number of users	Number of calls per user	Number of 'no' responses	Number of calls lost due to 'no' response	Calls lost due to reduced frequency of calling	Number of calls after policy change	Calls lost due to policy change	% Drop off
1.00	512	3748	245	1747	436	1565	2183	58.24
2.00	506	3322	314	1819	123	1380	1942	58.46
3.00	282	2008	194	1359	43	606	1402	69.82
0.50[a]	512	2438	200	1458	205	748	1663	68.21
4.00[b]	282	313	22	105	47	161	152	48.56

[a] This is a second round dollar amount; offered only to those who have already said 'no' to a higher dollar amount
[b] This is a second round dollar amount; offered only to those who have already said 'yes' to a lower dollar amount

The number of calls they would place per week if charged the suggested fee was also tallied and from these came the number of calls lost due to decreased calling, C_D. The total number of calls lost for each fee per call category, C_L, is therefore given by:

$$C_N + C_D = C_L \text{ (total number of calls lost)} \quad [12]$$

The total number of calls that would be made to the WeatherLine by respondents in this sample after a policy change to charge a set fee per call is given by:

$$C_T - C_L = C_R \quad [13]$$

And the percentage of drop-offs for any given fee level is therefore given by:

$$C_L / C_t * 100\% = \% \text{ drop-off} \quad [14]$$

The percentage drop-off rates are presented in Table 3. Based on the drop off rates in Table 3 and the total numbers of calls made annually, the gross revenue generating capacity of the WeatherLine from commercial users is calculated for each of the fee levels used in the questionnaire, and shown in Table 4.

6. Conclusions

This application of the contingent valuation method generated statistically significant (95% level) estimates of WTP across a number of commercial sectors that currently use the WeatherLine ATAD service. The cross-sectoral comparison indicates that the highest value per call placed to the WeatherLine is for the agricultural sector, at $2.17 per call. Other commercial sectors had statistically different levels of value per call (at the 95% level), for an average 'willingness to pay' of $1.20 per call for the sample, and a low of $0.60 per call for institutions including schools and hospitals. At roughly 13,750,000 commercial calls annually, this would result in estimated benefits of $16,500,000 per year to commercial users who use the service. However, the number of calls would be estimated to drop-off to about 40% of previous levels if a fee per call between $1.00 and $2.00 were to be charged.

Table 4. *Revenue generated by pay fee per call level*

Dollar amount charged per call	Number of calls lost	Number of remaining	Revenue generated annually
$1.00	8,008,000	5,742,000	$5,742,000
$2.00	8,038,250	5,711,750	$11,423,500
$3.00	9,378,875	4,371,125	$13,113,375

These methods are likely to be useful for economic valuation across industry sectors in other contexts, such as for estimating the value of other program services, developing premium packages, and targeting higher valued uses. The approach was used to provide estimates of the revenue generating capability of a current service, taking into account how users would be likely to respond to changes in fees. This could also be used to evaluate the potential value of a proposed service that is not yet offered.

References

Ackerman, J. A. (1994) The economic and environmental benefits of weather forecasts for salting operations in Devon, *Meteorol. Appl.* **1**: 109–112.

Alberini, A. (1995) Optimal bid designs for discrete choice contingent valuation surveys: single-bound, double-bound, and bivariate models, *J. Environ. Econ. and Management* **28**: 287–306.

Alberini, A., Kanninen, B. & Carson, R. T. (1997) 'Modeling Response Incentive Effects in Dichotomous Choice Contingent Valuation Data,' Land Economics, vol. 73, no. 3, August 1997, pp. 309–24.

Anaman, K. A. & Lellyett, S. C. 1996a. Assessment of the benefits of an enhanced weather information service for the cotton industry in Australia, *Meteorol. Appl.* **3**: 127–135.

Anaman, K. A. & Lellyett, S. C. 1996b. Producers' evaluation of an enhanced weather information service for the cotton industry in Australia, *Meteorol. Appl.* **3**: 113–125.

Anaman, K. A., Thampapilla, D. J., Henderson-Sellers, A., Noar, P. F. & Sullivan, P. J. (1995) Methods for assessing the benefits of meteorological services in Australia, *Meteorol. Appl.* **2**: 17–29.

Babcock, B. A. (1990) The value of weather information in market equilibrium, *Am. J. Agric. Econ.* **72**(1): 63–72.

Baquet, A. E., Halter, A. N. & Conklin, F. S. (1976) The value of frost forecasting: a Baysian appraisal, *Am. J. Agric. Econ.* **58**(3): 511–520.

Bishop, R. C., Champ, P. A. & Mullarkey, D. J. (1995) Contingent valuation. In *Handbook of Environmental Economics*, ed. Daniel Bromley. Oxford: Blackwell Publishers, pp. 629–654.

Bosch, D. & Eidman, V. (1987) Valuing information when ask preferences are non-neutral: an application to irrigation scheduling, *Am. J. Agric. Econ.* **69**(3): 658–667.

Cameron, T. A. (1988) A new paradigm for valuing non-market goods using referendum data, *J. Environ. Econ. and Management* **15**: 355–379.

Cameron, T. A. & Quiggin, J. (1994) Estimation using contingent valuation data from a 'dichotomous choice with follow-up' questionnaire, *J. Environ. Econ. and Management* **27**: 218–234.

Carson, R. C. (1985) Three essays on contingent valuation. PhD thesis, University of California, Berkley.

Cooper, J. C. (1993) Optimal bid selection for dichotomous choice contingent valuation surveys, *J. Environ. Econ. and Management* **24**: 25–40.

Farrow, R. (1994) Development of premium telephone weather services: a partnership between the public and the private sectors, *Meteorol. Appl.* **1**: 180–189.

Freeman, A. M. III. (1993) *The Benefits of Environmental Improvement: Theory and Practice*, Washington DC: Resources for the Future.

Hanemann, W. M. (1984) Welfare evaluations in contingent valuation experiments with discrete responses, *Am. J. Agric. Econ.* **66**(2): 333–341.

Hanemann, W. M. & Kanninen, B. (1996) The statistical analysis of discrete-response CV data, Working Paper no. 798, Department of Agricultural and Resource Economics, University of California at Berkeley, 110pp.

Hanemann, W. M., Loomis, J. & Kanninen, B. (1991) Statistical efficiency of double-bounded dichotomous choice contingent valuation, *Am. J. Agric. Econ.* **73**(2): 1255–1263.

Herdan, B. & Otten, H. (1994) Development of commercial applications for weather forecasts, *Meteorol. Appl.* **1**: 23–31.

Kanninen, B. J. (1993) Optimal bid design for double-bounded dichotomous choice contingent valuation, *Land Econ.* **69**: 114–125.

Katz, R. W. & Murphy, A. H. (eds.) (1997) *Economic Value of Weather and Climate Forecasts*. Cambridge and New York: Cambridge University Press.

Kite-Powell, H. L. & Solow, A. R. (1994). A Bayesian approach to estimating benefits of improved forecasts, *Meteorol. Appl.* **1**: 351–354.

Kopp, R. J., Pommerehne, W.W. & Schwarz, N. (eds.) (1997) *Determining the Value of Non-Market Goods: Economic, Psychological, and Policy Relevant Aspects of Contingent Valuation Methods*. Boston: Kluwer Academic Publishers.

Krinsky, I. & Robb, A. L. (1986) On approximating the statistical properties of elasticities, *Rev. Economics and Statistics* **68**: 715–719.

Lave, L. B. (1963) The value of better weather information to the raisin industry, *Econometrica* **31**: 151–64.

Leigh, R. J. (1995) Economic benefits of Terminal Aerodrome Forecasts (TAFs) for Sidney Airport, Australia, *Meteorol. Appl.* **2**: 239–247.

Maunder, W. J. (1970). *Economic Analysis of Weather*. London: Methuen & Co. Ltd., pp. 217–240.

Mitchell, R. C. & Carson, R. T. (1990) *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Washington DC: Resources for the Future.

Mjelde, J., Sonka, S., Dixon, B. & Lamb, P. (1988) Valuing forecast characteristics in a dynamic agricultural production system, *Am. J. Agric. Econ.* **70**(3): 674–684.

Mjelde, J. W., Hill, H. S. & Griffiths, J. F. (1998) A review of current evidence on climate forecasts and their economic effects in agriculture, *Am. J. Agric. Econ.* **80**(5): 1089–1095.

Perman, R., Ma, Y., McGilvray, J. & Common, M. (1999) *Natural Resource and Environmental Economics*, 2nd edn, New York: Pearson Education, Inc.

Rollins, K., Wistowsky, W. & Jay, M. (1997) Wilderness canoeing in Ontario: using cumulative results to update dichotomous choice contingent valuation offer amounts, *Canadian J. Agric. Econ.* **45**: 1–16.

Smith, K. & Vick, S. D. (1994) Valuing weather radar benefits for winter road maintenance: a practical case example, *Meteorol. Appl.* **1**: 173–177.

Sol, B. (1994) Economic impact of weather forecasts for forest fires, *Meteorol. Appl.* **1**: 155–158.

Solow, A. R., Adams, R. F., Bryant, K. J., Legler, D. M., O'Brien, J. J., McCarl, B. A., Nayda, W. & Weiher, R. (1998) The value of improved ENSO prediction to U.S. agriculture, *Climatic Change* **39**(May): 278–95.

Tice, T. & Clouser, R. (1982) Determination of the value of weather information to individual corn producers, *J. Appl. Meteorol.* **21**(4): 447–452.