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Measuring the Elasticity of Substitution of Wages for Municipal Infrastructure: A Comparison of the Survey and Wage Hedonic Approaches

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I. INTRODUCTION

In an earlier issue of this journal, Cummings, Schulze, and Mehr [4] derive estimates for social benefits attributable to investments in municipal infrastructure in boomtowns. Those benefits estimates were based on the hedonic price estimation method, where wages were used for determining hedonic "prices" relevant to municipal infrastructure.

In several recent studies, public goods valuations based on the hedonic price method have been compared with valuations derived via survey (contingent valuation) methods, e.g., Bishop and Heberlein [1] and Brookshire *et al.* [2]. Interest in comparisons of public good values estimated with hedonic price and contingent valuation (CV) methods results, in large part, from the ongoing controversy as to the accuracy, or reliability, of public good values estimated by survey methods (see Bishop and Heberlein [1]; Rowe and Chestnut [6]; and Chap. 6 in Cummings, Brookshire, and Schulze [5]).

Given the controversy surrounding the usefulness of survey methods as a means for estimating social valuations of public goods, the idea of comparing survey values with market-related, hedonic prices has obvious appeal as a means for analyzing, at a minimum, relationships between values drawn from the two very different estimation techniques (see Chap. 6 in Cummings, Brookshire, and Schulze [5]). Herein lies the motivation for this short paper which has as its purpose a comparative analysis of survey values and hedonic prices for the public good: municipal infrastructure. The "value" of interest is the elasticity of substitution of wages for municipal infrastructure (η). The rationale for focusing on the elasticity measure η is discussed in Section II.

Estimates for η using hedonic price ($\hat{\eta}$), developed in the earlier paper by Cummings, Schulze, and Mehr [4], and survey ($\bar{\eta}$) methods are developed in Section III. In Section IV comparative analyses of $\hat{\eta}$ and $\bar{\eta}$ are conducted; concluding remarks are offered in Section V.

II. ELASTICITY OF SUBSTITUTION OF WAGES FOR MUNICIPAL INFRASTRUCTURE

Within a theoretical context, Cummings and Schulze [3] have considered optimal timepaths for investments in municipal infrastructure in boomtowns. Central to the

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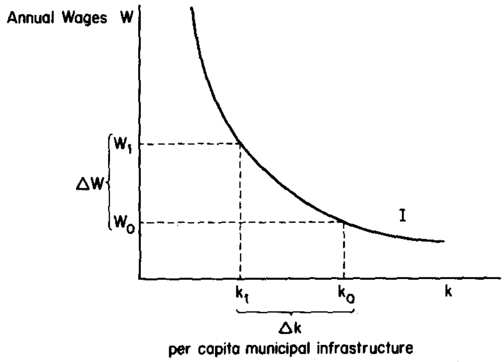

FIG. 1. The tradeoff between infrastructure and wages

propositions developed by Cummings and Schulze was the elasticity of substitution of wages (W) for per capita infrastructure (k), denoted as η. The parameter η was shown to be important in determining optimal paths for the labor force, investments for the energy producing firms and municipal infrastructure, as well as for an efficiency tax. More generally, wage-infrastructure trade-offs were related to the problem of valuing municipal infrastructure as a public good as shown in Fig. 1. The vertical axis represents annual money wages (W) and the horizontal axis is the level of per capita municipal infrastructure (k). If one assumes, for simplicity, the situation where individuals have identical preferences, one can value the annual services of municipal infrastructure by identifying wage-infrastructure trade-offs reflected by the indifference curve I.

Two obvious approaches for deriving empirical estimates of this indifference curve, characterized by η, are available. First, an individual worker living in a community with a fairly high level of municipal infrastructure, k_0, and a wage W_0 can plausibly be induced to live and work in a boomtown community characterized by a lower level of infrastructure k_1 only by an increase in his wages to W_1. For simplicity we ignore, for the moment, moving expenses and assume perfect information; in this case, ΔW as shown in Fig. 1 is a compensated measure of the willingness to pay (benefits) for increasing infrastructure by Δk. Further, if one assumes (as do Cummings and Schulze) a constant elasticity of substitution along the indifference curve, then $(dW/dk)(k/W) = \eta =$ constant. If data are collected for wage levels and levels of infrastructure in boomtowns and other communities, one can then estimate a hedonic wage equation:

$$\ln \hat{W}_j = \hat{\beta}_0 + \sum_{i=1}^{m} \hat{\beta}_i \ln X_{ij} + \hat{\eta} \ln k_j. \tag{1}$$

Thus, the wage level in community j is determined by the level of infrastructure, k_j, and by m other explanatory factors, X_{ij} (e.g., climatic variables, distance to nearest metropolitan area, etc.). The estimated coefficient $\hat{\eta}$ then allows calculation of willingness to pay for infrastructure.

The second approach is to directly ask individuals for their willingness to pay for an increase in infrastructure. Referring again to Fig. 1, households in a boomtown with a level of infrastructure k_1 can be asked how much, at most, they would be willing to pay (i.e., give up money wages) to obtain a higher level of infrastructure, k_0. If households give accurate (preference revealing) answers, then bids will be equal to ΔW as shown in Fig. 1.

This observation suggests the hypothesis to be tested in this work, viz., that the elasticity of substitution between wages and infrastructure estimated in the hedonic wage equation, specified above as $\hat{\eta}$, will be the same as the average elasticity of substitution $\bar{\eta}$ calculated from household surveys.

To briefly anticipate the discussion that follows, the results show that the estimate for $\hat{\eta}$ based on the hedonic measures does not differ, statistically, from the estimates for $\bar{\eta}$ drawn from the three separate surveys. Moreover, the statistical test to be employed is of some interest in and of itself, since the method used compares a regression coefficient with a sample mean.

III. THE ELASTICITY MEASURES

The hedonic measure for η of interest here was developed by Cummings, Schulze, and Mehr [4]. Since this work is reported elsewhere, a brief sketch will suffice for our present purposes. Pooled cross-sectional and time series data from 26 towns in the Rocky Mountain area obtained in 1977 provided 209 observations which were used by the authors to estimate (1) above. The resulting estimate for the hedonic wage equation was

$$\ln W = 8.43 + \underset{(0.022)}{0.183} \ln D - \underset{(0.017)}{0.035} \ln k \qquad R^2 = 0.34 \qquad DF = 206, \tag{2}$$

where standard errors are given under the estimated coefficients and D, a community's road distance from the nearest SMSA, is used as a surrogate for relative isolation and/or transportation costs. Surprisingly, inclusion of other available explanatory variables such as data on climate did not significantly improve the estimated equation. Thus, based on the hedonic measure, a 10% increase in per capita infrastructure is associated with a 0.35% decrease in income—the elasticity of substitution between wages and k is $\hat{\eta} = -0.035$.

The second phase of research involved the use of a "bidding game," or a "contingent valuation study" (survey techniques), designed to elicit individuals' maximum willingness to pay for posited increases in the level of municipal infrastructure. In 1980, surveys were conducted in Grants and Farmington, New Mexico and Sheridan, Wyoming, which were among the 26 towns included in the hedonic wage study. Subjects were chosen at random outside of shopping centers in each community. In brief, the structure of the interview process follows; the questionnaire used in this study is given in an Appendix. First, the present level of municipal infrastructure (k_1) across functions (fire, police, recreation, water supply, sewage, streets and roads, and general government) was described via a board on which, for each function, the value of capital facilities was represented by colored checkers, each of which had a value of $100,000; thus, with $500,000 in capital for fire protection, the fire protection column would have 5 checkers. Second, the individual was asked to put him/herself into the position of a municipal planner, and then asked if he/she would in any way reallocate the existing k, among

TABLE I

Characteristics of Surveyed Populations

Community	Sample size	Average household income (000)	Average age	Employment						
				Mining	Construction	Trade–Services	Government	Housewife	Retired	Other
Farmington	278	29	34	80	42	100	9	13	6	28
Grants	115	26	38	40	17	27	3	10	2	16
Sheridan	93	31	36	21	17	19	1	25	0	10

functions. The result—the existing capital stock optimally allocated across functions —was then recorded. Third, the individual was asked for his/her maximum willingness to pay for a 10% increase in the community's stock (expressed in dollars rather than percent); the 10% increase in capital stocks would be allocated following the individual's "optimal" allocation of k_1. After the initial response (bid), he/she was asked if they would pay more if their original bid (received from all families in the community) was insufficient to cover associated costs—the bidding process was continued until a *maximum* willingness to pay was ascertained. Finally, household income and other demographic data were obtained; see Table I.

With data for individual maximum willingness to pay, ΔW, and wage income, W, the percentage change in income associated with a 10% change in per capita stocks of infrastructure can be calculated for each individual h and η_h is calculated as $(\Delta W/W)/(\Delta k/k)$. While of course η_h's vary across income groups and other demographic variables, the elasticity variables, the elasticity measure most comparable with the hedonic measure $\hat{\eta}$ is the *average* value of the η_h's in each community, denoted $\bar{\eta}$. These measures are given in Table II.

Theoretically, the contingent valuation and hedonic methods will produce identical measures for the parameter η so long as labor markets are resonably competitive. There are, however, several reasons why such equivalence might not obtain from empirical studies such as those described above. First, if the assumption of zero moving costs is violated in the hedonic wage study, this would likely result in an overestimate for $\hat{\eta}$, since wage differentials would be greater to compensate households for expenses associated with moving to boomtown communities. Second, if the assumption of perfect information is violated in the hedonic wage study, households might well move to a boomtown community for positive wage differential which are "too small," i.e., they might not realize how "bad" conditions really are. This would cause $\hat{\eta}$ to be an underestimate of its true value. Third, if the assumption of identical preferences is violated (see Brookshire *et al.* [2]), the

TABLE II

Mean Values of η from Surveys

Community	Sample size	Mean ($\bar{\eta}$)	VAR($\bar{\eta}$)
Sheridan	93	−0.042	0.00608
Grants	115	−0.037	0.00096
Farmington	278	−0.040	0.00331

hedonic rent gradient will overestimate willingness to pay for a public good. Fourth, any survey-related biases, such as strategic bidding and information bias, in the contingent valuation study could obviously produce overestimates or underestimates for the η's (see Schulze *et al.* [8]). Fifth, comparisons of a measure (the hedonic wage) based on 1977 data with bidding game measures based on 1980 data might be biased to the extent that construction and consumer price indices (1977–1980) differ. Finally, as suggested to the authors by an anonymous reviewer, the potential for biases is introduced by the fact that the hedonic measure is based on *existing* stocks of infrastructure, while the survey measure is based on optimally distributed stocks of infrastructure. As seen in the following section, these considerations have little apparent effect on the estimates for the parameter h; the estimates for that parameter derived from the contingent valuation and hedonic approaches are statistically identical.

IV. A COMPARISON OF ELASTICITY MEASURES

A statistical comparison of the values of $\bar{\eta}$ obtained from the contingent valuation studies which are sample means, with the estimate of $\hat{\eta}$ (a regression coefficient) obtained from the OLS regression on Eq. (1) is in certain respects similar to the Behrens–Fisher problem considered by, for example, Scheffé, [7]. This problem usually is thought of as arising when the quantities to be compared are sample means and two assumptions are satisfied:

(i) the data used to compute the sample means are independently drawn from normal populations, and

(ii) the ratio of the underlying population variances is unknown.

In the case at hand, the aim is to determine whether there exists a statistically significant difference between a sample mean and a regression coefficient. That situation by itself does not require any restructuring of the Behrens–Fisher problem. The relatively large samples reduce the importance of the normal population assumption. Further, in light of the vastly different data generating mechanisms inherent in the hedonic wage and survey approaches, the unequal variance assumption appears to be warranted. Because the survey communities, Grants, Farmington, and Sheridan were included among cities from which data were taken for the hedonic wage regressions, the sample statistic $\hat{\eta}$ and the $\bar{\eta}$'s may not be independent. However, each of the $\bar{\eta}$ estimates were obtained from only one of the 26 cities observed in computing $\hat{\eta}$. As a consequence, the covariance between these two types of estimates is likely to be small relative to their variance.

The values of $\bar{\eta}$ shown in Table II can be compared with $\hat{\eta}$ under the null hypothesis that $E(\bar{\eta}) = E(\hat{\eta})$ by calculating the value of the statistic shown in Eq. (3),

$$t_f \sim \frac{\bar{\eta} - \hat{\eta}}{[\mathrm{VAR}(\bar{\eta}) + \mathrm{VAR}(\hat{\eta})]^{1/2}}, \tag{3}$$

where VAR$(\cdot)$ denotes the variance of the statistic indicated. As demonstrated by

TABLE III
Comparison of $\bar{\eta}$ to $\hat{\eta}$

Community	t_f	f
Sheridan	0.088	101.8
Grants	0.057	183.8
Farmington	0.083	324.1

Welch [9], that statistic is approximately t distributed with f degrees of freedom, and f is obtained according to Eq. (4),

$$f = \frac{[\text{VAR}(\bar{\eta}) + \text{VAR}(\eta)]^2}{[(\text{VAR}^2(\bar{\eta})/\text{DF}(\bar{\eta})) + (\text{VAR}^2(\hat{\eta})/\text{DF}(\hat{\eta}))]}, \tag{4}$$

where the DF($\cdot$) notation denotes degrees of freedom. In general, Eq. (4) will not produce an integer value of f. Nevertheless, as shown in Table III, all values of f used here are greater than 100 so that rounding to the nearest integer has virtually no effect on the critical value of t selected.

The small values of t_f from the three comparisons made, also shown in Table III, indicate that the null hypothesis $E(\bar{\eta}) = E(\hat{\eta})$ would not be rejected at any commonly chosen level of significance; we therefore conclude that there is no statistical difference between the hedonic measure $\hat{\eta}$ and the survey measures denoted $\bar{\eta}$. Nevertheless, there are two qualifications regarding this conclusion that warrant consideration.

First, the covariance between $\bar{\eta}$ and $\hat{\eta}$ may not be equal to zero so that the test statistic given in Eq. (3) may be in error. In this situation, the variance of $\bar{\eta} - \hat{\eta}$ would be given by $\text{VAR}(\bar{\eta} - \hat{\eta}) = \text{VAR}(\bar{\eta}) + \text{VAR}(\hat{\eta}) - 2\text{COV}(\hat{\eta}, \bar{\eta})$. Since $\text{COV}(\hat{\eta}, \bar{\eta})$ is most likely positive, then ignoring this term would cause the denominator of Eq. (3) to be too large and the resulting test would be biased in favor of not rejecting the null hypothesis, $E(\bar{\eta}) = E(\hat{\eta})$. However, given the small values of t_f reported in Table III, the value of $\text{COV}(\bar{\eta}, \hat{\eta})$ could not possible be large enough to reverse the conclusions reported. For example, in the comparison for Sheridan, even if $\text{COV}(\bar{\eta}, \hat{\eta}) = 0.001326$, which would make the correlation coefficient between the two measures equal to unity, the t statistic would only increase from the value of 0.088 shown in Table III to 0.115. That latter figure still would be too low to warrant rejecting the null hypothesis at conventional significance levels.

Second, the approach used to test $E(\bar{\eta}) = E(\hat{\eta})$ might be questioned because of the large standard errors associated with the estimates of $\bar{\eta}$. Even 80% confidence intervals about the three values of $\bar{\eta}$ shown in Table 2 are quite large and bracket the value zero. In light of the results of previous contingent valuation studies, however, large standard errors of average bids should be expected because of variation in tastes across individuals. Moreover, the errors in the contingent valuation method may be fully reflected in the reported standard error of the mean, while the total magnitude of error in a corresponding hedonic estimate can only be known after performing a detailed specification analysis on the underlying regression model. But more importantly, the absolute difference between these three average values of $\bar{\eta}$ and $\hat{\eta}$ always is less than or equal to 0.007. That value is approximately 40% of the standard error of the hedonic estimate $\hat{\eta}$. Therefore, even low level confidence intervals about $\hat{\eta}$ would bracket each of the three values of $\bar{\eta}$.

V. CONCLUDING REMARKS

The most commonly used technique for valuing public goods of a capital nature has been the hedonic approach. However, survey methods have been used with increasing frequency as an alternative when data for hedonic analysis are unavail able. The presumption has been that the hedonic approach based on use of actual market data, rather than on hypothetical responses, is inherently superior—a notion that is shown to be spurious by V. K. Smith (Chap. 11 in Cummings, Brookshire and Schulze [5]). The experiment reported in this paper, along with a number of other experiments (see Cummings, Brookshire, and Schulze [5, Chaps. 6, 13]), suggests that survey approaches yield value estimates that are comparable with those derived from hedonic (and travel cost) methods. It must be acknowledged, however, that survey *and* hedonic (*and* travel cost) values may be biased vis-a-vis "true" measures for individual preferences for public goods.

Obviously, considerably more attention must be given to questions concerning the quantification of biases in values derived from the CVM, as well as from all other methods used in estimating benefits attributable to public goods. In setting our expectations in these regards, however, we may do well to reflect on Arrow's comments concerning the perspective for considering questions related to accuracy: "It appears to me that in the estimates produced by our technological colleagues... errors on the order of one to ten are considered to be perfectly normal.... The question is, should we be disturbed if we think that our error is within the factor of plus or minus fifty percent, or even double that? Let's talk about ratios of 3 : 1 or 5 : 1; compared to the other sources of ignorance in most of these environmental fields... is this something to worry about?" (Cummings, Brookshire, and Schulze [5], p. 185).

APPENDIX

Questionnaire Used in Contingent Valuation Study

My name is __________ and I am a student at the University of __________.
We are conducting a survey concerning people's preferences for municipal facilities. Would you be good enough to give me a few minutes of your time?

(Town) has $__________ in buildings, land and equipment that are used to provide municipal services. By department (REFER TO BOARD), there is about $__________, invested in fire facilities or about ______% of total investment, represented by fire stations, ambulances, equipment, etc. (REPEAT THIS FOR EACH DEPARTMENT, MAKING SURE INDIVIDUAL HAS A GRASP ON WHAT INFRASTRUCTURE MEANS.)

Suppose you were elected the city's planner, and that you could redistribute these amounts of money that have been invested in these departments. This means you could decrease the investments in some categories and increase others, or perhaps, keep them the way they are. Will you indicate the changes that you would make on this board?

1. After re-allocation, number of chips in each category:

Fire	Police	Recreation	Water facilities	Sewage & sanitation	General government	Streets & roads
___	_____	________	_______	________	_________	_______

2. Suppose now that the *total* budget for municipal facilities in (Town) was to be increased by $______ *per family*, this would mean that the value of total facilities would increase by $___________. We would like to know how much you would be willing to pay in each future year to see this $__________ invested in your community. To get at this question, we play a "bidding game," where I ask you for bids. For example, would you be willing to pay $______/year to see this investment made?

Suppose that with every family in (Town) paying your bid it was insufficient to attract this $___________ investment. Would you pay $1 more? ... $2 more? ...

Final Bid $___________

3. Demographic data.

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