CHAPTER IV

THE VALUATION OF LOCATIONAL AMENITIES: AN ALTERNATIVE TO THE HEDONIC PRICE APPROACH

by
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It is widely recognized that the process of urbanization creates both positive and negative externalities. The important question from the viewpoint of welfare economics is what value consumers place on these externalities. If consumers regard large cities as yielding net disutility then a regression of wages on population and population density will indicate how much individuals must he compensated for living in urban areas. This figure, as suggested by Tobin and Nordhaus, may be used to adjust welfare measures for the trend toward urbanization. Alternatively, this information may be used to determine optimal city size (Henderson, Tolley). Even if cities on net yield positive utility the valuation of particular disamenities is useful for public decisionmaking. This has led to a large number of studies (Getz and Huang, Hoch and Drake, Mayer and Leone, Rosen 1977) which have computed hedonic prices for locational amenities such as crime, pollution, congestion, and local public goods.

The purpose of this paper is not simply to add to a growing empirical literature, but to present an alternative method of valuing locational amenities. In the studies cited above, marginal valuations of amenities are obtained by regressing the wage rate in city i on the level of amenities in that city. This equation is usually interpreted as an equilibrium locus of wage-amenity combinations since, if workers are mobile, wage rates should adjust to reflect differences in site-specific amenities. According to the theory of hedonic prices (Rosen 1974, 1977) the gradient of the wage-amenity locus represents consumers' marginal willingness to pay for amenities evaluated at market equilibrium.

In this paper valuations of environmental goods are obtained by estimating labor supply functions for various occupations, under the assumption that the supply of labor will be lower in cities where disamenities are high. The labor supply functions to be estimated are derived from a model of locational choice in which workers select not only the city in which they live but their housing site within the city. Conditions for equilibrium in the land market in each city lead to an equation in which the real acceptance wage for each occupation in city i is a function of employment in that occupation and the level of amenities in the city. By specifying explicitly the form of individuals' utility functions it is possible to relate the coefficients of the labor supply function to the coefficients of the utility function, which in turn may be used to compute willingness to pay.

The novelty of this approach is that it explicitly considers the spatial character of individual cities. By ignoring the spatial dimension of the problem, previous studies have been forced to assume that individuals within each city are exposed to the same level of amenities, regardless of where they live. In our model it is possible to find assumptions about the geographic distribution of amenities, and about utility functions, which allow the acceptance wage to be expressed as a function of the level of amenities at a single location within the city; or, when this is not possible, to assess the bias introduced by measuring amenities at a single point.

The spatial model also allows us to determine precisely what is meant by the "value of reducing crime" or the "value of improving air quality." Under the assumptions below the labor supply function captures the value which individuals place on amenities both at their residence and at their work site. The coefficients may therefore be used to estimate the maximum willingness to pay for an equal proportionate change in an amenity throughout the city.

The theoretical model which underlies the valuation of amenities is presented in section I below. In order to obtain reliable estimates of willingness to pay one must take account of factors affecting the demand for labor which allow firms to compensate workers for urban disamenities. This is accomplished in section I by developing a model in which industries expand in cities where locational amenities -- proximity to input and output markets, low property tax rates -- are favorable. In section II the empirical counterpart of this model is developed and labour supply functions are estimated for nine one-digit occupations using data from the 1970 Census of Population. The labor supply functions indicate which amenities are most important in consumer location decisions and whether they are valued equally by all occupational groups. The regression results are used in section III to illustrate how marginal valuations of amenities may be inferred from the coefficients of the labor supply function.

4.1 An Equilibrium Model of Urban Location

To keep the notation simple the model below is presented for the case of a single occupation and two industries, one of which produces for home consumption and the other for export. Generalization to the case of several occupations and industries is considered in section I.C.

The model used to justify our valuation of amenities consists of a large number of cities, each one of which contains a business district surrounded by residential areas. Below, it is assumed that each city is circular with the business district at the city center; however, our results continue to hold as long as all industry is located in a single area and residential districts are indexed by their distance from this area.

Within each city live identical workers who can costlessly migrate from one city to another, but who must work in the city in which they reside. Outside of cities live landowners who rent land within the city boundaries to workers and firms, the capital owners who own the capital equipment used by firms.

For simplicity it is supposed that the size of the CBD and the boundary of the city are both fixed. Thus what is analyzed is a short-run situation where the period of analysis is long enough to allow workers to move freely from one city to another but not long enough to allow the size of the city to adjust to this migration. This short-run equilibrium persists until the city re-zones agricultural areas as residential districts and provides them with various public services (sewers, water, electricity). Since it is unlikely that real-world data reflect a long-run equilibrium situation, the assumption that the city boundary is fixed does not seem inappropriate for empirical work.

For the purposes of empirical work it is also convenient to assume that the land in the city center is located at a single point in space so that no distinctions need be made among locations in the CBD. This may be defended on the grounds that land in the CBD of a city is usually small relative to the total area of the city. All land in the center of city i is thus assumed to rent at the same price. The spatial character of the rest of the city is acknowledged by expressing the rent on land in residential areas as a function $r_i(k)$ of k, the distance of the annulus from the boundary of the CBD.

A. Assumptions Regarding Workers

We shall assume that workers in all cities are identical and work a fixed number of hours in the CBD of the city in which they live at a wage of w_i per period. Each period the worker makes a fixed number of trips from his home to the CBD. In urban location models it is customary to assume that the cost of commuting from the residence to the CBD is an increasing function of distance traveled but does not depend on the worker's income. This assumption, however, is incompatible with the log-linear utility function employed below, which implies that a constant fraction of income is spent on transportation. To be consistent with that utility function transportation is treated as another good which the individual purchases, and commuting costs are not subtracted from Income. The disutility associated with commuting is instead captured by including the term $k^{-\xi}$ in the utility function.

It is assumed that each worker receives utility from the size of his residential site, q, from the quality of local goods consumed, x, ad from y, the amount of imports consumed. Utility is also received from site-specific amenities, which may vary from one location to another within the city.

In general, the fact that individuals in the same city are exposed to different levels of crime, pollution, and even temperature, leads to problems of aggregation when cities are the units of observation in empirical work. This poses no problem here as long as the value of each amenity at location k can be expressed as the product of the value of the amenity measured in the CBD and a dispersion function which describes how the amenity varies with distance from the point of measurement. In the case of industrial pollution, for example, emissions are generated in the CBD and spread to other parts of the city. Pollution at location k can therefore be written $P_i a_i(k)$ where P_i is pollution measured in the CBD and $a_i(k)$ is a function which is decreasing in k.

Following this approach we denote by $A_i a_i(k)$ the level of amenities which the individual experiences at his housing site, k. (For convenience, only a single $A_i a_i(k)$ is included in the utility function.) The level of amenities in the CBD, A_i, enters the utility function separately since most amenities which are consumed at home are enjoyed at the work site also.

Since the individual takes locational amenities as given, utility

$$U_i = Bq^{\beta} x^{\alpha_1} y^{\alpha_2} A_i^{\eta} [A_i a_i(k)]^{\delta} k^{-\xi}, \qquad \alpha_1+\alpha_2+\beta = 1 \tag{4.1}$$

will vary, for constant q, x, and y, according to the city and neighborhood in which the individual lives. For any location (i,k) the individual can determine his maximum utility be choosing q, x and y to maximize (4.1) subject to the constraint:

$$w_i = r_i(k)q + P_{1i}x + P_{2i}y, \tag{4.2}$$

where the prices of land, local goods, and imports are all taken as given. The utility maximization problem yields demand functions for residential land and for x and y. These can, in turn be substituted into (4.1) to yield the indirect utility function:

$$V_i(k) = Cw_i r_i(k)^{-\beta} P_{1i}^{-\alpha_1} P_{2i}^{-\alpha_2} A_i^{\eta+\delta} a(k)^{\delta} k^{-\xi}, \qquad C = B\beta^{\beta}\alpha_1^{\alpha_1}\alpha_2^{\alpha_2}, \tag{4.3}$$

which gives the level of utility in each neighborhood of each city as a function of site-specific amenities, income and prices.

The fact that individuals are free to choose their residence implies that in equilibrium the level of utility $V_i(k)$ must be identical in all locations. Furthermore, if city i is small relative to the size of the country, $V_i(k)$ may be regarded as exogenously determined and hence $V_i(k)=V^*$ for all i and k. Worker mobility thus implies that rents, wages and the prices of local goods must adjust to compensate for differences in amenities across locations. The extent of this adjustment depends on how much individuals value amenities, as reflected by the coefficient $\eta+\delta$.

It might at first appear that $\eta+\delta$ could be inferred by solving the locational equilibrium condition $V_i(k)=V^*$ for w_i and estimating the resulting equation using data across cities. Unfortunately this leads to an equation involving land prices and amenities, which vary within, as well as across, cities. This problem is solved, however, if (4.3) is used to derive the supply function for labor.

In order to obtain the labor supply function (4.3) may be solved explicitly for $r_i(k)$ to give each individual's maximum willingness to pay for land at location k,

$$r_i(k) = (C/V^*)^{1/\beta} w_i^{1/\beta} P_{1i}^{-\alpha_1/\beta} P_{2i}^{-\alpha_2/\beta} A_i^{(\eta+\delta)/\beta} a(k)^{\delta/\beta} k^{-\xi/\beta} . \qquad (4.4)$$

Since land will be sold to the highest bidder (4.4) also represents the equilibrium rent function in city i. Now for the land market to be in equilibrium the population (labor force) in city i must be such that the demand for land at distance k from the CBD equals the supply. Equivalently, if $2\pi k dk$ is the fixed supply of land at distance k, then the number of persons living in ring k, n(k), must satisfy:

$$n(k) = \frac{2\pi k dk r_i(k)}{\beta w_i} \qquad (4.5)$$

Substituting for $r_i(k)$ from (4.4) and integrating from k=0 to $k=\bar{k}_i$, the fixed boundary of ith city, yields the number of workers in the city as a function of amenity levels and the wage,

$$N_i = \int_0^{\bar{k}_i} n(k)dk = Mw_i^{(1-\beta)/\beta} P_{1i}^{-\alpha_1/\beta} P_{2i}^{-\alpha_2/\beta} A_i^{(\eta+\delta)/\beta} f_i(\bar{k}_i), \qquad (4.6)$$

where $M = 2\pi\beta^{-1}(C/V^*)^{1/\beta}$ and $f_i(\bar{k}_i) = \int_0^{\bar{k}_i} k^{1-\xi/\beta} a_i(k)^{\delta/\beta} dk$.

Equation (4.6) is the supply function of labor in city i, which may be used to estimate the coefficient of amenities in the utility function. For purposes of estimation, however, it is convenient to write the labor supply function in the form:

$$(w_i/P_i)^* = c + \frac{\beta}{1-\beta} N_i^* - \frac{\eta+\delta}{1-\beta} A_i^* - F_i(\bar{k}_i), \quad P_i \equiv (\alpha_1+\alpha_2)/(1-\beta), \qquad (4.7)$$

where asterisks denote logarithms of the variables. The variable on the left-hand side of (4.7) is the real acceptance wage -- the money wage in city i divided by a price index in which all commodities except residential land are weighted by the fraction of the budget spent on each. The acceptance wage is an increasing function of N_i since, if land is fixed, an increase in population will raise rents and thus the income necessary to maintain V*. Amenities such as sunshine and clean air enter equation (4.7) with negative coefficients, while disamenities, for which individials must be compensated, increase the acceptance wage.

Note that due to the multiplicative nature of utility only the value of amenities in the CBD appears in the supply function. The dispersion function $a_i(k)$ which captures the fact that individuals in each city are exposed to different levels of amenities, is subsumed in $F_i(\bar{k}_i)$. Since in the short run $\bar{k}_i$ is exogenous, we shall regard the $\bar{k}_i$ as independent drawings from a probability density function. $F_i(\bar{k}_i)$ can then be regarded as an error term which is independently though not identically distributed for all cities. If, however, the dispersion functions are identical in all cities, then the error terms $F(\bar{k}_i)$ will be independently and identically distributed for all i.

The coefficient of amenities in the utility function can therefore be estimated by regressing the real wage in city i on employment and on amenities in city i. In order to obtain consistent estimates of $\eta+\delta$, however, it is necessary to first identify factors which determine the demand for labour in each city.

B. Assumptions Regarding Firms

Rather than develop a model which explicitly treats firm migration we assume that there is a production function for industry X and for industry Y in each city. Differences in natural resource endowments, transportation costs and locational amenities lead to differences in production costs among cities which, in turn, explain the growth of industry in each city.

For city i the production function of the export industry may be written:

$$Y_i = D_2 N_{2i}^a L_{2i}^b K_{2i}^c S_{2i}^d E_{2i}^f, \qquad a+b+c < 1, \tag{4.8}$$

where L_{2i} denotes land and other raw material inputs, N_{2i}, labor inputs, K_{2i}, capital goods, S_{2i}, pollution generated by the industry and E_{2i} environmental goods which affect the production process. The latter might include climate or the level of air pollution in the city. Population, N_i, may also enter the production function as a proxy for agglomeration economies if these are relevant for industry Y.

We shall assume that industry Y behaves as a price-taker in all markets. Thus given output price, input prices, and a tax on effluents, the industry determines profit-maximizing levels of inputs L, N and K and a level of emissions, S. Industry X behaves analogously.

Although each industry regards input and output prices as exogenous, the wage, the price of land in the CBD, and the price of local goods are determined by equilibrium conditions in product and factor markets in city i. Equating the aggregate demand for land in the CBD to the size of the CBD, the aggregate demand for labor to the right-hand side of (4.6) and the supply of X to the aggregate demand for X yields a system of three equations which may be solved for the price of land, the wage, and the price of X. The equilibrium level of employment (population) may be found by substituting the equilibrium wage into (4.6) and the quantity of local goods produced obtained by substituting P_{1i} into the aggregate demand function for X.

Environmental goods which depend on output or on population are also determined by market equilibrium conditions. The level of pollution in the CBD of city i may be expressed as a function of industrial emissions, $S_{1i}+S_{2i}$, and weather conditions in the CBD. Crime, which depends on population and on the wage, must also be regarded as endogenous.

In the model outlined here the size of industry in city i, and hence the demand for labor, depends on the parameters of the production function and on input and output prices. For the purposes of empirical work, however, it is the exogenous factors which determine the size of industry that are important. These enter the model through the variable E_i and by affecting the prices of capital goods, natural resources, and the price of exports.

As indicated above the output of industry Y is sold in national markets at a price $\bar{p}$ which may be regarded as exogenous to each city. The price received by firms in city i, however, will fall short of $\bar{p}$ by the cost of shipping Y to market. Since shipping costs depend on the distance of city i from the central market and on the intervening topography , one would expect the demand for labor to be higher in cities close to output markets which have access to cheap sources of transportation.

The prices of natural resources and capital goods, which are assumed to be traded in centrally located markets, may also be regarded as exogenous to firms in city i. The delivered cost of these inputs (and hence the damand for labor) depends on the proximity of the city to input markets and on the feasibility of using low-cost means of transportation, e.g., water v. air.

Finally, the demand for labor should be higher in areas where land prices are low. Although the price of land in the CBD is endogenous to city i, it is affected by the size of the CBD and by the property tax rate, both of which are determined by the government in the short run and are treated as exogenous in our model.

C. Generalization to Several Occupations

The model of sections A and B, although locically consistent, is based on assumptions which are difficult to accept in empirical work. By treating all workers as identical the model ignores variations in skill levels and job experience which explain a large proportion of variation in wages across cities. The model also imposes the stringent requirement that all individuals have identical preferences. These assumptions may be relaxed by estimating labor supply functions for separate occupational groups; however, it must first be demonstrated that the coefficients of the disaggregated labor supply functions have the same interpretation as the coefficients of equation (4.7).

Suppose in the model above that there are several classes of workers, with each class possessing different skills or years of job experience. This means that a distinction will have to be drawn among categories of labor in the production functions for X and Y, with each type of labor entering the production function with a different coefficient. There will as a result be a separate demand function for each type of labor; however, as long as factor markets are perfectly competitive, generalization to several occupational groups is straightforward.

Deriving the supply functions for labor presents more difficulties. Suppose for simplicity that members of each occupational group are identical and work a fixed number of hours in the CBD at the wage paid to their group. While workers within each group have the same tastes, it seems reasonable to allow preferences for consumption goods and amenitities to differ among groups. The indirect utility function for each group will thus be of the form;

$$V_{ij}(k) = C_j w_{ij} r_i(k)^{-\beta_j} P_{1i}^{-\alpha_{1j}} P_{2i}^{-\alpha 2_j} A^{\eta_j+\delta_j} a(k)^{\delta_j} k^{-\xi_j} \qquad (4.9)$$

where parameters are subscripted to allow for differences in tastes among groups.

As in the case of a single category of labor, the labor supply function for each occupational group is derived from that group's location decision. In locational equilibrium all members of the occupational class must experience the same utility regardless of the neighborhood or city in which they live. Thus V_{ij} must be constant for all i and k and equal to V_j^*. (If each city is small and open, the V_j^* can be considered exogenous to the city.) This equilibrium condition is used to determine where in each city members of group j will live. The group's labor supply function is then derived by summing the number of persons in each neighborhood, n(k), across all neighborhoods k in which members of the group reside.

The crucial step in the above procedure is determining the spatial distribution of occupational groups within each city. Equilibrium in the land market requires that land at each location be sold to the highest bidder. To determine the bid function for each occupation the locational equilibrium condition [(4.9) with $V_{ij}=V_j^*$] may be solved for $r_{ij}(k)$, group j's maximum willingness to pay for land at each location. Under certain assumptions these bid functions, if plotted against k, will be downward-sloping and will intersect any number of times. Each city will thus be divided into neighborhoods which are segregated on the basis of occupation, with neighborhood boundaries determined by the intersections of the $r_{ij}(k)$'s Summing the number of persons per annulus, n(k), across all k at which group j resides (K_{ij}) yields group j's supply function for labor,

$$N_{ij} = M_j w_{ij}^{(1-\beta_j)/\beta_j} P_{1i}^{-\alpha_{1j}/\beta_j} P_{2i}^{-\alpha 2_j/\beta_j} A_i^{(\eta_j+\delta_j)/\beta_j} \int_{k\varepsilon K_{ij}} k^{1-\xi_j/\beta_j} a(k)^{\delta_j/\beta_j} dl \qquad (4.10)$$

The trouble with this procedure is that the boundaries of the group j neighborhoods, which are determined by the intersections of the $r_{ij}(k)$'s cannot be treated as exogenous but themselves depend on w_{ij}. The integral on the left-hand side of (4.10) cannot therefore be regarded as a random error term, and omitting it from the equation will bias the coefficients of N_{ij} and A_i in (4.11).

$$(w_{ij}/P_i)^* = c_j^* + \frac{\beta_j}{1-\beta_j} N_{ij}^* - \frac{\eta_j+\delta_j}{1-\beta_j} A_i^* + \epsilon_{ij}^*. \qquad (4.11)$$

How serious this problem is depends on the extent to which current neighborhood boundaries depend on current wages and levels of amenities. To the extent that they do not the limits of integration in the supply function may be regarded as independent of w_{ij} and A_i, and the integral in (4.10) may be treated as a random error term.

4.2 Empirical Specification and Estimation of the Model

The model of section I implies that one may value urban amenities by estimating labor supply functions of the form (4.11). To illustrate this approach supply function were estimated for one-digit occupational categories using data from the 1970 Census of Population. The results of these regressions are presented below following a description of our empirical model.

A. Specification of the Labor Supply Function

To estimate equation (4.11) one must find empirical counterparts to the amenities A_i which influence consumer location decisions. One group of variables found to be important in previous studies are the amenities and disamenities associated with urbanization. Most regressions, for example, include air pollution, crime and congestion (population density) as measures of the disamenities of urban life while using some index of availability of goods and services (number of sports franchises, number of TV stations) to capture the advantages offered by large cities. In the context of our urban location model all amenities and disamenities associated with urban scale should he treated as endogenous variables. Our small sample size (n=28), however, makes it difficult to treat more than one or two variables as endogenous. Scale amenities must therefore be treated as exogenous, causing simultaneous equations bias, or must be omitted from the equation altogether.

To resolve this problem air pollution, measured by the arithmetic mean of sulfur dioxide, is included in the labor supply function as an endogenous variable. Crime is also included but is treated as exogenous on the grounds that crime rates are affected by law enforcement practices, by the racial composition of the population, and even by climate (Hoch), all of which are exogenous to the model of section I. The only measure of urban amenities explicitly included in the regression equation is availability of health facilities -- number of hospital beds per 100,000 and number of doctors per 100,000. Unlike other measures of availability of goods and services these variables are not very responsive to variations in income and can more reasonably be regarded as exogenous.

Scale amenities which are omitted from the labor supply function will be captured in part by the endogenous employment variable, N_{ij}. In equation (4.11) this variable represents the effect of land prices on wages and is expected to have a positive coefficient. If, however, N_{ij} enters the utility function as a proxy for scale amenities then its coefficient should be wirtten $(\beta-\gamma)/(1-\beta)$ where γ represents the net effect of scale amenities. If the amenities of urban life outweigh the disamenities then the sign of employment may actually be negative.

Other factors which are likely to affect location decisions are climate and scenic beauty. Although these variables can truly be regarded as exogenous, high correlation between individual amenity measures, together with a small sample, makes it difficult to include all relevant variables in the regression equation. Of the one dozen climate variables considered, only the two most significant, average July temperature and wind velocity, appear in the final equation. These variables should therefore be regarded as proxies for the amenities of climate, and their individual coefficients should be interpreted with caution.

A similar situation arises in the case of scenic amenities. Scenic amenities, which may be measured by proximity to the ocean or to the mountains, are closely related to the availability of recreational facilities (beaches, parks, skiing). Unfortunately the measure of recreational facilities used in our empirical work, number of national parks, state parks and national forests within 100 miles of each city, was highly correlated with a dummy variable = 1 if the city was located on the ocean and with a dummy variable indicating the availability of beaches. To avoid collinearity problems only a single variable, the coastal dummy, was retained in the final equation. Its coefficient should therefore be interpreted as a proxy for both recreational and aesthetic amenities.

An additional category of amenities to be considered is employment opportunities within each city. In our theoretical model employment opportunities are captured entirely by the wage rate w_{ij}. In reality, markets are imperfect and individuals must consider the probability of being unemployed. For married males the relevant variables are the unemployment rate in the individual's own occupation as well as some indicator of employment opportunities for women. If the ratio of females to males in the labor force were identical in all cities, then the ratio of females to males actually employed would indicate the availability of jobs for women. This variable, first suggested by Getz and Huang, appears in one set of regressions reported below. An alternate measure of employment opportunities, which is more in the spirit of our model, is the real median earnings of women in each city. This is included in the labor supply functions of blue collar males, as reported in Table II.

While both measures of employment opportunities for women are significant for some occupations, the unemployment rate for males is not and has been deleted from the labor supply function. The poor performance of the unemployment rate is probably due to the fact that aggregate unemployment is of little significance to members of specific occupations. Unemployment rates for one-digit occupations are, unfortunately, unavailable for the year 1970.

B. Identification of the Labor Supply Function

The model of Section I implies that the labor supply function must be estimated as part of a simultaneous equation system in which the real wage, employment, and air pollution are endogenously determined. Exogenous variables in the system which affect the location of industry but not of workers may be used to identify the labor supply function. The discussion in I.B suggests at least three such variables -- availability of raw material inputs, proximity to output markets, and availability of cheap transportation. The empirical counterparts of these are used as excluded exogenous variables in the 2SLS estimation of (4.11).

Availability of raw materials is measured by the value of farm products, the number of acres of commercial timberland and by value added in mining, all measured for the state in which the SMSA is located. Proximity to other cities is measured by the percent of goods (by weight) shipped at least 500 miles from the SMSA and by the percent of goods shipped within 100 miles of th SMSA boundary. High values of the former variable should indicate that a city is isolated from output markets, whereas high values of the latter should indicate the reverse. A dummy variable equal to 1 if the city is a port is included to indicate availability of cheap transportation.

Finally, as noted at the beginning of section I, the size of each city is regarded as fixed in our model on the grounds that we are dealing with a short-run equilibrium situation. Since land prices will affect the growth of industry, city size (in acres) and the effective property tax rate are both included as excluded exogenous variables in the estimation of the labor supply function.

C. Estimation of the Labour Supply Function

The labor supply functions presented in Tables I-III have been estimated using 1970 Census of Population data for 28 of the 39 cities for which BLS Cost of Living indexes are available. (A list of these cities and a description of data sources appear in the Appendix). In each of the regressions the dependent variable is the median earnings of all males who worked 50-52 weeks in 1969. The wage variable in each case is deflated by the BLS intermediate budget cost of living index, with the price of housing removed from the index, as indicated in I.A.

By including only those individuals who worked for the entire year, and by estimating labor supply functions for specific occupations one is able to control for some of the factors other than amenities which account for inter-city variation in wage rates. Median earnings, however, may vary due to differences in union membership, in educational levels and in years of job experience. Since data on union membership and on the ratio of union to non-union wages are available by region for one-digit occupations it is possible to adjust the earnings variable using the formula:

$$w_{observed} = (1-a)w_{non-union} + aw_{union}, \qquad (4.12)$$

where a represents the percentage of workers in unions. The non-union wage, obtained by solving (12), is the dependent variable in the regressions for blue-collar occupations.

To test the significance of human capital factors and racial discrimination in explaining variation in wages, median earnings in each occupations (undeflated by the cost of living index but adjusted for union membership) were regressed on the average age of workers in the occupation, on the percent of non-whites in the occupation and on the average school years completed by all males in the SMSA. In all cases the years of schooling variable, which is unavailable by occupation, was, not surprisingly, insignificant. The average age of the workforce, however, was positively related to the money wage for all occupations and was significant at the .05 level in all but two cases. Percent non-white was highly significant, with the expected negative sign, for laborers and service workers, the only two occupations employing a high percent of non-whites.

In the context of our model it seems most appropriate to treat average age and percent non-white as exogenous variables which affect the productivity of labor, as perceived by firms. Average age and percent non-white are therefore included as exogenous variables in estimating the labor supply function, the former for all occupations except managers and the latter for laborers and service workers only.

Finally, wage rates may vary across cities due to disequilibrium movements in workers and firms not allowed for in the model of section I. For example, an increase in the demand for labor in city i will put upward pressure on the wage rate and should be accompanied by an inflow of workers into the city. To allow for this possibility the net migration rate is included as an explanatory variable in one set of regressions.

4.3 Empirical Results

An important question to be answered by our empirical model is which groups of variables are most important in individuals' location decisions. A related question is whether these variables are the same for all occupational groups. To answer these questions Table 4.1 presents regression results for nine occupations with the same set of variables appearing in each equation.

In examining these results one must be careful to interpret individual variables as proxies for groups of amenities. Viewed in this way scenic amenities (coastal dummy), scale amenities (employment), and the availability of health facilities seem to be the most important factors in location

Table 4.1

Estimated Labor Supply Functions

(n = 28)	All Earners	Professional Workers	Non-Farm Managers	Sales Workers	Clerical Workers
Constant	6.0536***	4.8012***	5.9472***	4.3032**	4.089***
	(1.4295)	(1.7002)	(1.6454)	(1.9612)	(1.5067)
Employment	0.0273**	0.0257	0.0342**	0.0365**	0.0233*
	(0.0160)	(0.0196)	(0.0185)	(0.0206)	(0.0164)
SO_2	0.0219*	0.0231	0.0255*	0.0151	0.0209
	(0.0161)	(0.0193)	(0.0180)	(0.0204)	(0.0170)
July temperature	-0.4397***	0.0392	-0.0768	0.0386	-0.2247*
	(0.1327)	(0.1584)	(0.1525)	(0.1815)	(0.1397)
Wind velocity	-0.1087**	-0.1545**	-0.1507**	-0.0855	-0.0717
	(0.0576)	(0.0674)	(0.0658)	(0.0781)	(0.0608)
Doctors/100,000	-0.1381**	-0.1065	-0.1008	-0.0031	-0.1156*
	(0.0681)	(0.0807)	(0.0789)	(0.0941)	(0.0721)
Hospital beds/100,000	-0.0651**	-0.0376	-0.0228	-0.0637*	-0.0380
	(0.0338)	(0.0399)	(0.0392)	(0.0469)	(0.0355)
Crimes/100,000	+0.0743**	0.1070**	0.0785**	0.0503	0.0709**
	(0.0349)	(0.0422)	(0.0403)	(0.0472)	(0.0367)
Female/Male Employment	-0.0613	0.0335	0.0956	0.0094	-0.1900*
	(0.1206)	(0.1441)	(0.1394)	(0.1651)	(0.1277)
Coastal Dummy	-0.0639***	-0.0192	-0.0690**	-0.0938***	-0.0462**
	(0.0249)	(0.0303)	(0.0286)	(0.0338)	(0.0265)
R^2	.7429	.5916	.6047	.5499	.5637

(continued)

Note: All variables are in natural logarithms.

*** = Significant at .01 level, one-tailed test.

** = Significant at .05 level, one-tailed test.

* = Significant at .10 level, one-tailed test.

Table 4.1
(continued)

(n = 28)	Craftsmen	Operatives	Non-Farm Laborers	Service Workers
Constant	4.3419**	2.4042*	6.4412***	7.8618***
	(1.7232)	(1.5790)	(1.4466)	(2.2571)
Employment	0.0360**	0.0014	0.0344**	0.0356*
	(0.0200)	(0.0163)	(0.0143)	(0.0242)
SO_2	0.0155	0.0242*	0.0340**	0.0488**
	(0.0192)	(0.0179)	(0.0150)	(0.0250)
July temperature	-0.4680***	-0.4339***	-0.8984***	-0.8524***
	(0.1583)	(0.1441)	(0.1332)	(0.2117)
Wind velocity	-0.0904	-0.0352	0.0314	0.0342
	(0.0695)	(0.0635)	(0.0575)	(0.0899)
Doctors/100,000	-0.1241*	-0.0401	-0.1657**	-0.2321**
	(0.0814)	(0.0736)	(0.0680)	(0.1071)
Hospital beds/ 100,030	-0.0439	-0.1021***	0.0014	-0.0267
	(0.0407)	(0.0368)	(0.0338)	(0.0529)
Crimes/100,000	0.0496	0.0048	0.0385	0.0832
	(0.0414)	(0.0374)	(0.0347)	(0.0554)
Female/Male Employment	-0.3349**	-0.5548***	-0.2327**	-0.0220
	(0.1459)	(0.1356)	(0.1217)	(0.1905)
Coastal Dummy	-0.0869***	-0.0410*	-0.0293	-0.0054
	(0.0299)	(0.0262)	(0.0250)	(0.0398)
R^2	.7508	.7998	.8873	.7366

Note: All variables are in natural logarithms.

*** = Significant at .01 level, one-tailed test.

** = Significant at .05 level, one-tailed test.

* = Significant at .10 level, one-tailed test.

decisions: Each of these variables consistently has the expected sign and is asymptotically significant at the 0.10 level or better in six out of nine regressions.

The behaviour of employment is of particular interest since it is this variable which represents the effects of city size. In all occupations the coefficient of employment is positive, which would seem to imply that individuals must be compensated for living in large cities. One must, however, be cautious in drawing this conclusion. The coefficient of employment in the labor supply function β_1, depends not only on γ, the coefficient of city size in the utility function, but on β, the proportion of income spent on the housing site. Specifically,

$$\beta_1 = (\beta-\gamma)/(1-\beta). \tag{4.13}$$

Given $\hat{\beta}$ and $\hat{\beta}_1$, equation (4.13) may be solved for $\hat{\gamma}$, which is clearly increasing in both variables. The smallest value of $\hat{\gamma}$ implied by Table I occurs when $\hat{\beta}_1 = .0014$. Note that even if $\hat{\beta}$ were only .03, $\hat{\gamma}$ would still be positive (although small) indicating that cities yield net amenities to consumers. This conclusion, however, must be qualified by the fact that crime and air pollution, two disamenities partially associated with city size, are included separately in the regression equation and are often significant and positive.

One must also be cautious in interpreting the variable doctors/ 100,000, which may represent amenities other than health facilities. The coefficient of this variable is particularly large for laborers and service workers, groups for whom scenic amenities do not appear to be significant. Conversely, in cases where MD's is insignificant the coastal tummy is significant. This suggests that MD's/100,000 may act as a proxy for scenic amenities, an hypothesis which is not unreasonable if doctors take part of their income in the form of locational amenities. This hypothesis is also strengthened by casual inspection: San Francisco, Denver and New York are among the cities with the highest number of doctors per capita, whereas Wichita, Kansas is the sample minimum.

Of the remaining variables, crime is significant in five equations and is clearly more important for white-collar than for blue-collar workers. Air pollution, measured here by sulfur dioxide, has the expected positive sign for all occupations but seems to be more significant for blue-collar occupations. If this result appears surprising, it should be remembered that blue-collar workers are more mobile than highly-paid white-collar workers, whose location decisions are likely to depend on job-related amenities. Pollution and other locational amenities are therefore more likely to appear significant in the labor supply functions for blue-collar occupations.

This reasoning may explain why climate variables do not appear to be very significant for white-collar workers. (The two exceptions in the case of wind velocity are most likely due to the effect of wind on air quality.) For blue-collar workers average July temperature is highly significant and appears as an amenity in all cases. The extremely large coefficients of temperature may be due to the variable acting as a proxy for other climate variables or, since July temperature is higher in Southern cities, as a proxy for the large supply of unskilled labor often used to explain the lower level of wages in the South.

The remaining variable in the supply function, the ratio of female to male employment, is the more significant of the two measures of employment opportunities for women. As indicated in Table I this variable is not significant in the supply functions for highly-paid white-collar workers but is significant for clerical workers and for most blue-collar occupations, implying that the importance of employment opportunities varies inversely with the husband's income. It is interesting to note that these results are similar to those of Getz and Huang, who find female/male employment to be highly significant in labor supply functions estimated from the same set of data.

The results of using median earnings for women in place of female/male employment are reported in Table II. Female earnings is significant for only two occupations (operatives and laborers) but has a market effect on the coefficients of other variables whenever it is included in the equation. In general the coefficients of other amenities increase in absolute value and in significance. This may be the result of high pairwise correlations between female earnings and employment, crime, and doctors per 100,000 which are not present when female/male employment is used. For this reason the results presented in Table I should be viewed as more reliable.

To test the possibility that wage data reflect disequilibrium movements of workers, the equations in Table I were re-estimated with net migration included in non-log form. The net migration variable was significant only for while-collar occupations and these results are reported in Table 4.3. In all cases net migration has a positive sign, suggesting that wages for white-collar workers are higher in some cities due to an increase in the demand for labor to which workers have not fully adjusted. Adding net migration to the equation does not drastically alter the conclusions of Table 4.1, but does affect the relative importance of the pollution and employment variables. Sulfur dioxide is now significant in three out of four white-collar occupations, whereas employment is significant only in the aggregate labor supply function. This result is probably due to the positive correlation between employment and air pollution, which makes it difficult to separate the effects of the two variables.

The Valuation of Environmental Amenities -- An Illustration

We shall not illustrate, using the results of Table 4.1 - 4.3, how valuations of locational amenities can be inferred from the coefficients of the labor supply function. In the model of section I a given percentage change in A_i in the CBD of city i implies an equal percentage change in the amenity throughout the city. The amount an individual is willing to pay for this change may be defined as the largest amount of income one can take away from the individual without altering his utility. If the change in A_i is so small that it does not affect prices in city i then willingness to

Table 4.2

Labor Supply Functions of Blue-Collar Workers

(n = 28)	Craftsmen	Operatives	Non-Farm Laborers	Service Workers
Constant	8.1298***	8.9434***	9.2910***	8.1321***
	(1.0665)	(1.0216)	(0.8401)	(1.2702)
Employment	0.0527**	0.0228	0.0443***	0.0453**
	(0.0219)	(0.0152)	(0.0150)	(0.0254)
SO_2	0.0231	0.0402**	0.0410***	0.0447***
	(0.0214)	(0.0212)	(0.0155)	(0.0242)
July temperature	-0.5682***	-0.5964***	-0.9733***	-0.8525***
	(0.1709)	(0.1658)	(0.1339)	(0.2017)
Wind velocity	-0.1234*	-0.0890	0.0095	(0.0276)
	(0.0776)	(0.0746)	(0.0600)	(0.0900)
Doctors/100,000	-0.2128***	-0.1704**	-0.2221***	-0.2390***
	0.0780	(0.0754)	(0.0611)	(0.0918)
Hospital beds/ 100,000	-0.0319	-0.0921**	0.0038	-0.0264
	(0.0453)	(0.0435)	(0.0353)	(0.0530)
Crimes/100,000	0.0684	0.0639	0.0642*	0.0804
	(0.0525)	(0.0505)	(0.0409)	(0.0617)
Median Earnings, Females	-0.1659	-0.4299***	-0.1989*	-0.0119
	(0.1743)	-(0.1637)	(0.1355)	(0.2153)
Coastal Dummy	-0.0817**	-0.0290	-0.0265	-0.0088
	(0.0333)	(0.0308)	(0.0259)	(0.0391)
R^2	.6849	.7155	.8764	.7380

*** = Asymptotically significant at the .01 level.

** = Asymptotically significant at the .05 level.

* = Asymptotically significant at the .10 level.

Table 4.3

Labor Supply Functions of White-Collar Workers

(n = 27)	All Earners	Professional Workers	Non-Farm Managers	Sales Workers	Clerical Workers
Constant	5.3028***	3.6120**	5.0071***	3.4306*	3.4875**
	(1.4216)	(1.5818)	(1.6746)	(1.9937)	(1.5794)
Employment	0.0277*	0.0118	0.0206	0.0322	0.0050
	(0.0188)	(0.0215)	(0.0224)	(0.0244)	(0.0200)
SO_2	0.0263*	0.0332*	0.0388**	0.0232	0.0313*
	(0.0188)	(0.0210)	(0.0216)	(0.0240)	(0.0210)
July temperature	-0.4879***	-0.0478	-0.1421	-0.0176	-0.2622**
	(0.1305)	(0.1474)	(0.1537)	(0.1825)	(0.1449)
Wind velocity	-0.0704	-0.0882*	-0.0937*	-0.0382	-0.0304
	(0.0593)	(0.0659)	(0.0698)	(0.0823)	(0.0661)
Doctors/100,000	-0.1488**	-0.0831	-0.0802	-0.0086	-0.0790
	(0.0689)	(0.0755)	(0.0825)	(0.0989)	(0.0769)
Hospital beds/ 100,000	-0.0513*	-0.0346	-0.0253	-0.0523	-0.0477
	(0.0363)	(0.0393)	(0.0437)	(0.0524)	(0.0398)
Crimes/100,000	0.0702**	0.0887**	0.0639*	0.0450	0.0570*
	(0.0343)	(0.0385)	(0.0406)	(0.0482)	(0.0382)
Female/Male Employment	-0.1831*	-0.1618	-0.0539	-0.1300	-0.2756
	(0.1298)	(0.1447)	(0.1538)	(0.1822)	(0.1454)
Coastal Dummy	-0.0718***	-0.0315***	-0.0794***	-0.1014***	-0.0491**
	(0.0243)	(0.0275)	(0.0286)	(0.0338)	(0.0273)
Net Migration	0.0022**	0.0036***	0.0030**	0.0026*	0.0017
	(0.0012)	(0.0014)	(0.0014)	(0.0017)	(0.0013)
R^2	.7873	.7037	.6599	.6086	.5947

*** = Asymptotically significant at the .01 level.

** = Asymptotically significant at the .05 level.

* = Asymptotically significant at the .10 level.

pay, Δw_i, is defined implicitly by:

$$C w_i r_i(k)^{-\beta} P_{1i}^{-\alpha 1} P_{2i}^{-\alpha 2} A_i^{\eta+\delta} a(k)^{\delta} k^{-\xi} =$$

$$C(w_i - \Delta w_i) r_i(k)^{-\beta} P_{1i}^{-\alpha 1} P_{2i}^{-\alpha 2} (A_i + \Delta A_i)^{\eta+\delta} a(k)\ k^{-\xi}. \tag{4.14}$$

This can be simplified to:

$$\Delta w_i = w_i[1-(1+k)^{-(\eta+\delta)}], \qquad k \equiv \Delta A_i / A_i \tag{4.15}$$

where k denotes the proportional change in A_i.

Willingness to pay can thus be computed solely from knowledge of income and the exponent of amenities in the utility function. To estimate $\eta+\delta$ from the coefficient of A_i in the labor supply function, $-(\eta+\delta)/(1-\beta)$, requires knowledge of β, the proportion of income spent on the residential housing site. If employment acts as a proxy for scale amenities β cannot be inferred from the coefficient of N_i, however, valuations of A_i can be computed for alternate values of β.

To illustrate the use of (4.15), willingness to pay for one-, ten-, and twenty-percent changes in selected amenities are shown in Table 4.4 for an individual whose yearly income is $9,000. These figures are based on results reported in Table 4.1, and, in view of the discussion above, should be interpreted with caution.

Table 4.4 implies that an individual with the same preferences as a manager would be willing to pay between 0.68% and 0.80% of his income for a 10% reduction in the total crime rate. Since the cost on insuring one's possessions against theft is already included in the cost of living index, this valuation represents the phychic disutility attached to crime. These figures correspond closely to valuations of crime obtained by Rosen (1977), who estimates that individuals would be willing to pay between 0% and 1.16% of their income for a comparable reduction in the crime rate. The coefficient of violent crime in the labor supply functions estimated by Getz and Huang, 0.05, also suggests that our estimates of willingness to pay are reasonable.

The value placed on a reduction in sulfur dioxide, although low by comparison with crime, is higher than the figure obtained by Ridker and Henning in their important study of air pollution in the St. Louis SMSA. By regressing property value by census tract (1960) on site-specific amenities, Ridker and Henning estimate that a permanent decrease in SO_2 by approximately 30% would raise the value of an average home by $245. Based on figures in Table 4.1 the present discounted value of a 30% reduction in SO_2, calculated for a person earning the median income in St. Louis in 1960, is between $418 and $489, or roughly twice the figure cited by Ridker and Henning. One reason for this discrepancy is that under the

Table 4.4

Valuations of Environmental Amenities

	Crime (Managers)			Sulfur Dioxide (Laborers)			July Temperature (Operatives)		
	-1%	-10%	-20%	-1%	-10%	-20%	+1%	+10%	+20%
.19	$5.86	$61.2	$129	$2.50	$26.1	$55.1	$31.1	$294	$554
.10	6.51	68.0	143	2.77	29.0	61.2	34.6	326	613
.05	6.87	71.8	151	2.92	30.6	64.6	36.5	344	646

NOTE: All figures represent annual values of willingness to pay, computed for an individual with an income of $9,000.

assumptions of I.A. our figures capture willingness to pay for reductions in pollution at the work site and at home, whereas the property value approach measures willingness to pay at the residence only. Furthermore, part of our estimate may represent willingness to pay for a reduction in suspended particulates. Particulates, being highly correlated with sulfur dioxide, are omitted from the labor supply function to avoid problems of multicollinearity.

The least reliable estimates in Table 4.4 are those for summer temperature. In Tables 4.1 - 4.3 July temperature appears as an amenity, with individuals willing to give up income for above-average temperatures. Since the coefficient of temperature for laborers and service workers likely represents the effects of lower skill levels in the South, the estimates in Table 4.4 are computed using the more moderate coefficient for operatives. If evaluated at the sample geometric mean, 75°F, this figure implies that an individual earning $9000 is willing to pay between $294 and $344 per year for an increase in average temperature from 75° to 82.5°F. While not unreasonable, this figure is higher than valuations implied by hedonic price regressions (see Meyer and Leone) and should be regarded as purely illustrative.

In the case of a dichotomous amenity, e.g., the coastal dummy, equation (4.15) no longer applies and willingness to pay must be calculated from

$$\Delta w_i = w_i(1-e^{\zeta}) \tag{4.16}$$

where ζ is the coefficient of the dichotomous amenity in the utility function. Using (4.16) Table 4.1 implies that a manager will give up between $660 and $770 if his income is $12,000. This figure, of course, must be regarded as approximate since the coastal dummy reflects other scenic amenities as well.

Finally, equation (4.15) may be used to infer how much of the husband's earnings a family would be willing to give up in order to increase the earning opportunities for the wife. Theory suggests that a family should not give up an equal amount of the husband's earnings if the shadowprice of the wife's time at home exceeds that of the husband. In Table 4.2 the highest significant coefficient of female earnings is -0.43, obtained for operatives. This implies that a male operative will relinquish at most 4% of his earnings for a 10% increase in real female earnings. If this figure should seem small, recall that it is based on the behavior of all operatives, some of whom are not married or do not have working wives.

4.4 Conclusion

This paper has presented a method of valuing environmental amenities using a model which describes the location of workers within as well as among cities. This allows us explicitly to deal with the fact that individuals within the same city are exposed to different levels of amenities. As long as individuals have log-linear utility functions the value of an amenity to an individual located anywhere in the city can be computed from the coefficients of an aggregate labor supply function which includes the level of the amenity measured at a single point within the city.

To illustrate the proposed method of valuing amenities labor supply functions were estimated for nine occupations using data from the 1970 Census of Population. The results of these regressions are of interest quite apart from the problem of valuing amenities since they indicate which groups of variables are important in inter-urban location decisions. Based on the signs and asymptotic significance levels of the regression coefficients crime and scenic amenities, measured here by a coastal dummy variable, seem to be the most important environmental goods in the location decisions of white-collar workers. Pollution (SO_2) is significant for three out of four blue-collar occupations, and is important for white-collar workers if net migration is included in the equation. Employment opportunities for females, whether measured by median real earnings of females or by the ratio of female workers to male workers, seems to be an important consideration in the location decisions of blue-collar workers, as does the availability of health facilities (MD's/100,000, hospital beds/100,000). Surprisingly, climate variables do not seem very important, especially for white-collar workers, although this conclusion must be qualified by the fact that it is hard to separate the effects of climate from other variables.

The original motive for this paper was to place a value on the amenities and disamenities associated with urbanization. Subject to certain qualifications, willingness to pay for reductions in crime and air pollution are presented in section 3.3 above. While one would not want to place too much confidence in the figures, it is clear that certain groups of individuals must be compensated for these urban disamenities. The same, however, cannot be said for the other effects of city size. For all occupations the coefficient of the urban scale variable is positive, which appears to indicate that urbanization yields not disutility. One cannot, however, regard the coefficient of employment as the marginal value of city size. The latter, as shown sbove, is very likely positive, indicating that the effects of urbanization not captured by other variables yield positive utility.

CHAPTER V

VALUATION REVEALING GUESSES: A REPORT ON THE EXPERIMENTAL TESTING OF A NON-MARKET VALUATION PROCEDURE

by
William R. Porter and Berton J. Hansen

This paper describes a survey method that can be used to measure the public's valuation of a public good. In its simplest form, the method attempts to determine the aggregate valuation of a public good (or change in a public good) by a group of consumers. It is designed to provide each respondent with strong incentive to (a) consider the valuation question seriously and (b) to disclose unbiased information about the public good valuation.

The method consists of asking each surveyed respondent to guess as close as possible to the "true average valuation" of the others in the group. Before guessing each person is told that if his guess is within α% of the actual average of the other peoples' guesses that he will be paid a large prize of β dollars. The change of winning the price provides each respondent with the incentive to attempt seriously to guess the average guesses of others, and since his most important information about others' true valuations is his own valuation, his guess will, if properly interpreted, reveal unbiased information about his own true valuation of the public good.

The underlying hypothesis in such a technique is that people base their guesses about the average of a characteristic in others on the level of that characteristic in themselves plus a partial but unbiased belief about their own relative position in the group.

Now since it is impossible to test such a hypothesis for a characteristic like people's true valuation of a public good, we have designed and conducted an experiment in guessing about the average of a measurable, but not commonly known, characteristic of members in a well-defined group. The results of this experiment were used in designing and interpreting a survey method of public good valuation.

5.1 Description of the Experiment-in-Guessing

A random sample of students drawn from the population of students at the University of California, Riverside (enrolled during the Winter Quarter of 1978) were sent copies of the attached letter.

The students who responded to the letter were scheduled for individual appointments during weekday mornings where they were read the following instructions and questions:

Procedure During Interview of "Experiment in Guessing"

[Establish identity of interviewee and close door for privacy].
[Record student control number __________].

The questions I will ask you are related to the amount of money that is usually carried by UCR students. Your answers will be strictly confidential.

First, will you please count the amount of money (U.S. currency and coins only) that you are now carrying. (Record amount __________(M)]

Second, what is the average amount of money that you carry in the morning of a school day? [Record amount __________(A)]

In the following question you will have an opportunity to win $50.00. Therefore, please pay close attention to what I will ask you to do, and do not answer until you are sure that you understand the situation.

You are one member of a group of 20 UCR students who will answer this question. Each of you will guess a number based upon a clue that I will give to all of you. The one member of the group who guesses closest to the average of the 20 guesses will win $50.00. Here is the clue: The number guessed should be close to the amount of money that an average UCR student carries in the morning of a school day. [If the student indicates that he does not understand, then tell him: "You are to guess as close as possible to the average guess of the others, realizing that all of you have been given the same clue." Reread the clue].

What is your guess? [Record amount __________(G)]

Thank you very much. That concludes the interview. As soon as we calculate the averages for each group, we will notify the winners. That will be in approximately 3 weeks. Thank you again for your help.

A total of 107 students were interviewed, and upon completion of the interviews the averages were calculated, and the winners were notified and paid their prizes in cash.

The objective of the experiment was to see if there was a systematic relationship between the value of a person's guess G_i about others' average behavior and his idea of his own average behavior N_i. The idea being that in the analogous public good method we would be attempting to measure the unknown ΣN_i by using the known ΣG_i. Therefore the fundamental question is: What is the nature of the random distribution of ΣG_i about the true value ΣN_i, and how does that distribution change as the sample size n gets large?

Our purpose in asking the first question in the procedure concerning

M_i was to focus each respondent's attention on the exact amount of money he currently was carrying so that he could more accurately form a judgment about the average amount he normally carries, N_i. It also provided an objectively measurable quantity ΣM_i as a check on the accuracy of beliefs about one's average behavior.

The characteristic -- the average amount of money that one carries -- was chosen for the experiment because it is something (like one's own valuation of a public good) that is known by each about himself but is very imperfectly known by each about others. Therefore when asked to guess about the average of this characteristic in others, it is natural to use one's own best knowledge (of oneself) plus some idea of one's relative position.

The results of the experiment provide a strong indication that people do base their guesses about others on knowledge about themselves and that their aggregate guesses are very accurate estimates of the average true value of the characteristic. The statistical results are presented below.

(Student number 25 was removed from the sample because his money carrying behavior was so extremely different than the other students that we could not expect their guesses to take account of his behavior. Student number 25 was carrying $423.87 at the time of the interview and he said that he carries an average of $150.00 each day).

Mean value of "Average Amount Carried":

$$= \frac{1}{106} \sum_{i=1}^{106} N_i = 5.6715$$

Mean value of "Average Guess":

$$\overline{G} = \frac{1}{106} \sum_{i=1}^{106} G_i = 5.8075$$

Suppose we assume that the average amount carried by a student is a random variable

(1) $N_i = \mu + \eta_i$, where μ is the "true" average amount carried by the entire population and η_i has a normal $(0,\sigma^2_\eta)$ distribution.

Suppose each student's guess G_i is a random variable defined by

(2) $G_i = N_i + \varepsilon_i$, where ε_i has a normal $(0,\sigma^2_\varepsilon)$ distribution.

Then we can write

(3) $G_i = \mu + \omega_i$, where $\omega_i \sim N(0,\sigma^2_\omega)$ and $\sigma^2_\omega = \sigma^2_\eta + \sigma^2_\varepsilon + 2\text{cov}(\eta,\varepsilon)$

In a procedure where we do not know the value N_i (such as in the public good case), then using equation (3) we can use the observations on the G_i's and our knowledge of the distribution of ω_i to estimate the value of μ.

Suppose we consider the measured $\bar{N}$ to be the true population mean μ, then the estimate of the variance of ω_i calculated from the data is:

$$\delta^2_\omega = (3.812)^2$$

Using this estimate we can calculate the sample sizes that are required to achieve various levels of accuracy in the measurement of μ. Let $R_\beta(\alpha)$ denote the sample size required to be $(100\beta)\%$ certain that $\bar{G}$ is within $(100\alpha)\%$ of μ. Therefore $R_\beta(\alpha)$ is the smallest integer n required to guarantee that

$$P[\frac{1}{n}\sum_{i=1}^{n} G_i - \mu \leq \alpha\mu] \geq \beta$$

The following table shows selected values of $R_\beta(\alpha)$.

Table 5.1

α	$R_{.80}(\alpha)$	$R_{.90}(\alpha)$	$R_{.95}(\alpha)$
.10	75	123	174
.05	297	489	695
.01	7,425	12,225	17,355

By analogy, if the value of σ^2_ω is similar, then these numbers indicate that using a guessing technique for public good valuation will allow us to be 90% certain of obtaining a measure that is within 10% of the true social value by interviewing as few as 123 randomly selected consumers in the area. Of course, the value of σ^2_ω may not be the same, however, we will obtain an estimate of σ^2_ω as the interviews proceed, and it is possible to use a sequential technique to determine when the sample size is sufficient for a given level of accuracy.

A very important property of this procedure is that it provides a measure of the accuracy of the estimate obtained, and it is impossible to say the same thing of previously used methods. Further experimental studies are needed to substantiate the unbiasedness property of this type of procedure, however the results of our own experiment indicate that the method is quite promising.

Based on the results of the guessing experiment we propose the following method of determining the public good valuation by a specific group.

Public Good Guessing Procedure

For each of the selected respondents:

1. Describe the exact proposed change in the public good from level A to level B in a way that enables the respondent to form a clear conception of the difference.

2. Define a person's true valuation of the change from A to B as: the most that a person would be willing to pay per month in order to have B rather than A if that were the only way he could obtain B.
Alternative Definition: The amount per month that would be just slightly more than a person would be willing to pay in order to have B rather than A if that were the only way he could obtain B.

3. Read the following statement to the respondent:

   You are one member of a group of ______ people selected from (describe the population) who will guess a number based upon a clue that will be given to all of you. If your guess is within a% of the average of the guesses of the others then you will receive a price of β dollars. The clue is that your guess should be close to the average true valuation of the (described) public good by the people in the (described) population. What is your guess?

The above method of having each respondent attempt to guess the average of others' guesses where each knows that the others are given the same clue and are also trying to guess the average of the guesses is designed to avoid bias that originates from strategic behavior. To see that this is a potential problem, consider the following two-stage guessing procedure.

Two-Stage Procedure

Ask each member of a selected group the following questions:

1. What is your true valuation of the change from B to A?

2. You are one member of a group of ______ persons who have been asked the preceding question, If you can guess within α% of the average of the others' stated valuations (given in their answers to question 1.), then you will win a prize of β dollars. What is your guess?

The potential bias in the two-stage procedure originates with the possibility of strategic behavior in response to the first question. Since the respondent is offered no incentive to answer truthfully to question (1), [indeed, it is impossible here to use a prize as incentive for truthfulness since the respondent knows that there is no method of verification] it is natural for him to consider the effect his response will have on either a project approval or a project financing decision. As soon as he forms a belief about this relationship then he is rational to give a stated valuation that he believes will influence the outcome in his favor. The fact that his subjective belief about the relationship may be incorrect does not alter the fact that it is costless for him to overstate or understate his valuation in the direction of his own perceived interest, and therefore, he probably will. When he is asked to guess the average stated valuations of the others, he will immediately realize that they also had incentive to distort their responses; hence, in order to win the prize, he must guess in the direction of their distortions rather than toward what he believes is their true average valuation. To argue that people are too unsophisticated to go quickly through this complicated chain of reasoning when responding to such seemingly hypothetical questions is to ignore the fact that even ordinarily dull people become quite suspicious when their own self interest may be involved. The result of this is that the average guess in the Two-Stage Procedure is likely to be biased in an unpredictable direction.

In contrast to the Two-Stage Procedure, the proposed Public Good Guessing Procedure offers no net incentive for strategic behavior. Each person has incentive to guess a number that is as close as possible to the average of the guesses by others. If each believes that the others are trying (as the clue suggests) to guess close to the true average valuation, then he will seriously attempt to guess near what they believe is the true average valuation. Neither he nor they have any incentive for over or under bidding; therefore, the average of the guesses is likely to be close to the average of the true valuations. The results of the guessing experiment suggest that this is indeed the case. Any incentive to state a guess that will strategically affect the outcome of the public good decision is offset by the incentive to win the cash prize, if the prize is high enough.

5.2 Incentive Structure of the Proposed Public Good Guessing Procedure

In contrast to the Two-Stage Procedure, the proposed Public Good Guessing Procedure does not reference people's guesses to previously stated valuations or bids. Instead, it uses a simultaneous guessing method having only the given clue, "the average true valuation of the public good by the people in the described population," as a common reference point. Each respondent knows that none of the respondents can exactly know the "average true valuation;" however, each has incentive (in the form of the prize) to attempt to guess what other people think this value is, since the prize is won by guessing close to the average guess of others. The respondents will use strategic behavior; however, in this case (if the prize is large enough), the objective of the strategic behavior will be to win the cash prize rather than to affect the outcome of the public good decision. The Guessing Experiment conducted at the University of California, Riverside, indicated that if the respondents do use strategic behavior to win the prize, then their aggregate guesses will accurately reveal their aggregate true valuation of the public good. Therefore, we see that rather than attempting to eliminate strategic behavior, the proposed method redirects the respondent's strategy in a way the reveals public good valuation.

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16. ABSTRACT

The research presented in this volume of a five volume study of the economic benefits of air pollution control explores various facets of the two central project objectives that have not been given adequate attention in the previous volumes. The valuations developed in these volumes have all been based on a partial equilibrium framework. W.R. Porter considers the adjustments and changes in underlying assumptions these values would require if they were to be derived in a general equilibrium framework. In a second purely theoretical paper, Robert Jones and John Riley examine the impact upon the aformentioned partial equilibrium valuations under variation in consumer uncertainty about the health hazards associated with various forms of consumption.

Two empirical efforts conclude the volume. M.L. Cropper employs and empirically tests a new model of the variations in wages for assorted occupations across cities in order to establish an estimate of willingness to pay for environmental amenities. The valuation she obtains for a 30 percent reduction in air pollution concentrations accords very closely with the valuations reported in earlier volumes. The volume concludes with a report of a small experiment by W.R. Porter and B.J. Hansen intended to test a particular way to remove any biases that bidding game respondents have to distort their true valuations.

17. KEY WORDS AND DOCUMENT ANALYSIS

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