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The estimation of marginal utility of income for application to agricultural policy analysis

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Abstract

A quality-of-life index (QLI), a proxy measure of utility, is constructed by factor-weighted and simple-summation weighted aggregation of socio-psychological measures of well-being. The socio-psychological measures were constructed from quality of life domains taken from selected years of the General Social Surveys [General Social Surveys, 1972–1993: Cumulative Code Book. Principal Investigator, James A. Davis; Director and Co-Principal Investigator, Tom W. Smith — Chicago: National Opinion Research Center, 1993. (National Data Program for the Social Sciences Series, no. 13).]. The Quality of Life Indices (QLI) indices are regressed on selected socio-demographic variables using quadratic, Cobb-Douglas, square root, and semilog functional forms. QLI is much influenced by income, education, and health. As measured here, QLI is not much influenced by year of measurement, sector, or by region of residence. Much variability in the QLI is unique to individuals, and our results are suited to predict group, rather than individual well-being. Practitioners computing the benefit–cost ratio for a public program, project, or policy can weight dollars by income groups with marginal utilities derived from this study. That methodology will matter: even the 'conservative' quadratic equation indicates that the marginal utility of income (MUI) for families with very low incomes is half as large as for families with median incomes. © 1997 Elsevier Science B.V.

1. Introduction

The paradigm of utility maximization is the core of demand and social welfare theory. Marshallian demand-and-supply measurement, although based on utility maximization, has evolved explicitly, accounting for the fact that utility is not measurable per se (see Pollack and Wales, 1978). The perception that utility is subjective and buried in the psyche has restrained social scientists from directly estimating utility, however, this may be accomplished. Although social welfare theory holds that interpersonal utilities are not comparable, the use of aggregate economic measures such as the gross domestic product (GDP) as a basis for policy analysis belies that assertion. By assuming that more GDP is good (without regard to its distribution), policymakers make the value judgment that a dollar of income not only contributes to well-being, but also that well-being is enhanced equally whether dollars are accrued by poor or wealthy individuals.

The perceived inability to measure utility has not hindered economists from making statements about marginal utility (MU) in applied economics. The new welfare economics paradigm used by neoclassical economists divides economics into equity (wealth and income distribution issues) and efficiency (input/output efficiency). Applied mainstream economists have emphasized the efficiency dimension and discarded the equity criterion. Many social scientists (e.g., Goldschmidt, 1968, 1978; Strange,

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1988) have held that equity is the most important dimension of economics and have rendered to economic efficiency the same obscurity that neoclassical economists have rendered to equity.

The motives of those emphasizing either equity or efficiency are not in doubt. Both groups are concerned about the well-being of people. Neoclassical economists implicitly assume that the marginal utility of income (MUI) is constant per dollar and equal for everyone so that maximizing efficiency maximizes utility. On the other hand, social scientists who emphasize equity implicitly assume individuals are sufficiently efficient, motivated, and social-minded so that market incentives are not of consequence for the general welfare. Both positions have elements of truth and error.

Improved estimates of MUI can help bridge the gap between equity and efficiency in economics. Such measures are required to assess the impact on the general welfare of public policies influencing the level and distribution of wealth. Measures of utility are also important to predict risk avoidance or preference behavior of farmers and others. Measures of utility can help economists to develop farm enterprise plans that farmers are likely to adopt to increase their level of satisfaction. In the public policy arena, measures of MU can help to determine whether people are better off from a revision in income tax rates, from income transfer programs, or from a resource development project (based on its utility-weighted cost–benefit ratio).

Social indicators providing insights into diverse relationships that determine well-being of society are available and helpful. However, because social indicators lack a common unit of measurement (such as money used to aggregate economic indicators into economic accounts), they have not been aggregated into a workable system of social accounts, despite valiant proposals to do so by (Fox, 1983).

The objective of this study is to construct a quality of life index (QLI) that approximates a social welfare utility function from empirically measured socio-psychological indicators of well-being. A secondary objective is to determine whether aggregation weighted by factor analysis is measurably superior to aggregation by simple summation of socio-psychological indicator variables to form a QLI. The constructed QLI is intended for group rather than interpersonal comparisons of well-being. Thus, the index is better suited for policy analysis than for microeconomic analysis.

2. Conceptual background

Assume the social welfare function for society:

$$U = U(Y_1, Y_2, \dots, Y_n, X) \tag{1}$$

where U is utility of society, Y_i is income of individual i ($i = 1, 2, \dots, n$), and X is a vector of nonmonetary sources of utility. Designating MU of income for individual i as U_i, the change in utility from a program or policy changing incomes of individuals may be expressed as

$$\begin{aligned}\Delta U = {} & U_1 \Delta Y_1 + \sum_{i \neq 1} U_i(\partial Y_i / \partial Y_1)\Delta Y_1 + \partial U_x(\partial X/\partial Y_1)\Delta Y_1 \\ & + U_2 \Delta Y_2 + \sum_{i \neq 2} U_i(\partial Y_i / \partial Y_2)\Delta Y_2 + \partial U_x(\partial X/\partial Y_2)\Delta Y_2 \\ & \vdots \\ & + U_n \Delta Y_n + \sum_{i \neq n} U_i(\partial Y_i / \partial Y_n)\Delta Y_n + \partial U_x(\partial X/\partial Y_n)\Delta Y_n.\end{aligned} \tag{2}$$

From this expression, it is apparent the change in utility may be aggregated from income increments of individuals as:

$$\Delta U = \sum_{i=1}^{n} U_i \Delta Y_i \tag{3}$$

if the MUI U_i for individual i is independent of changes in income of individual j, and if nonmonetary sources X of satisfaction are not influenced by changes in income. Whereas these assumptions may be acceptable, the traditional implicit assumption that $U_i = 1$ (so that $\Delta U = \Sigma \Delta Y_i$) is much less acceptable. Empirical measures of U_i as weights are needed but are unavailable. Textbooks (see Varian, 1992, Chap. 22) provide a theoretical framework but are of little help in supplying weights U_i.

If an income restraint:

$$Y = \sum_{i=1}^{n} Y_i \tag{4}$$

is added to Eq. (1) to form a Lagrangian expression, the first-order maximization conditions indicate that

MUIs of all individuals need to be equal to maximize U for society, i.e.,

$$\partial U/\partial Y_i = \partial U/\partial Y_j \quad i \neq j \tag{5}$$

If aggregate income is not fixed, the conditions for utility maximization change. Given aggregate fixed resources, Z (a constant-dollar aggregate of material resources such as air, raw minerals, water, along with labor), and production relationships embodying technology for individual i to turn raw materials Z_i into output (income) Y_i, the Lagrangian expression for utility maximization is:

$$U^* = U(Y_1, Y_2, \ldots, Y_n, X) + \lambda(Z - Z_1 - Z_2 - \ldots - Z_n). \tag{6}$$

Assuming that the MU for individual i is independent of resources used by another, Z_j, and also is independent of X, then the first-order conditions to maximize the social welfare function are:

$$\begin{aligned} U_1^* &= U_1(\partial Y_1/\partial Z_1) - \lambda = 0 \\ U_2^* &= U_2(\partial Y_2/\partial Z_2) - \lambda = 0 \\ &\vdots \\ U_n^* &= U_n(\partial Y_n/\partial Z_n)\lambda = 0 \\ Z &= Z_1 + Z_2 + \ldots + Z_n. \end{aligned} \tag{7}$$

These equations imply that for utility maximization, the MU per dollars worth of resources must be equal or

$$U_i \frac{\partial Y_i}{\partial Z_i} = U_j \frac{\partial Y_j}{\partial Z_j}. \quad i \neq j \tag{8}$$

For utility maximization in society, a highly productive individual would utilize resources to expand marginal productivity $\partial Y_i/\partial Z_i$, generating income (output) that drives his or her MU down. The lesson of Eq. (8) is that societal utility maximization does not require equal MUI among individuals but may call for incentives providing higher income (output) and attendant lower MUI to those who are more productive.

Practical use of the foregoing conceptual framework to calculate Eq. (3), for example, requires estimates of the MUI which may differ by income level, occupation, and other characteristics of gainers and losers from public projects and policies. These marginal utilities in turn can be used in project or policy analysis. As noted earlier, the typical approach in benefit–cost analysis is to weight benefits and costs by dollars, implicitly assuming MUI is constant and equal for all persons and all dollars.

Schreiner, 1989 postulated that project benefits and costs should be distributed among society based on marginal utilities of consumption. Traditionally, the ratio of discounted benefits to costs is used to measure economic efficiency. To measure equity, ad hoc judgments are sometimes based on how the income/wealth of gainers compares with that of losers. A more rigorous procedure suggested by the above conceptual framework is to group gainers into income classes, weighting benefits in each class by their respective MUI, and relate the result to costs also weighted by MUI among classes. The resulting social benefit–cost ratio weds equity and efficiency domains as a guide to allocation of resources for improving the well-being of society.

3. The estimation of MU

The empirical estimation of MU has proceeded along two distinct lines. The first is by the standard gamble or preference elicitation techniques using the von Neumann-Morgenstern approach. The second approach is to estimate MU by using socio-psychological measures of well-being taken from personal interviews.

In the standard gamble technique, individual utility functions are formed using data obtained from personal interviews, where the respondent specifies preferred choices from sets of alternative payoffs and probabilities (see Halter and Mason, 1978; Hildreth and Knowles, 1982; Lin et al., 1974; Binswager, 1980; Machina, 1987, p. 122). Agricultural economists have measured parameters of utility functions by simulated and actual gambling situations. The disadvantages of this approach are (1) small non-random samples arising from heavy respondent burden and difficult questionnaires, (2) the confounding of utility and gaming effects so that utility derived out of additional income per se cannot easily be disentangled from utility derived out of taking risks for monetary gain, and (3) the persistent violations of the expected utility axioms as shown in the literature (see Shoemaker, 1982; Machina, 1987). Machina, 1987 reviews choice under uncertainty and shows that violations of expected utility theory arise from nonlinearities in probabilities (e.g. the Allais Paradox), preference reversal phenomenon and framing effects.

In the second or socio-psychological survey approach, personal measures of well-being are employed to estimate MU (see Harper and Tweeten, 1977; Tweeten and Mlay, 1986). This report extends the empirical and conceptual framework of Tweeten and Mlay, 1986 beyond the quadratic utility function to include various functional forms. In addition, more years of data are used to increase the reliability of estimates and allow tests for the intertemporal stability of MU.

Even with properly validated indicator variables, the socio-psychological approach poses at least two problems. First, the survey instrument measures the subjective or perceived well-being rather than actual utility. Second, agreement among social scientists is incomplete regarding domains of life and their weights in measuring well-being.

We employ factor-weighted and simple-summation aggregation to construct a direct measure of utility from social-psychological variables found in General Social Surveys, 1972–1993. Regarding the first problem, individual responses to the socio-psychological attitudinal scales may be subjective but the analysis converting individual responses into an overall utility measure for groups can be objective. Although imprecise, the estimates derived in this study using objective scientific procedures are likely to be an improvement over value judgments by politicians of the MUI.

4. Measurable domains of life experience

Measurable domains of life experience must be used in constructing a QLI as a proxy for utility. Tweeten and Mlay, 1986 proposed the following candidates for domains or subindices (for further discussion, see Coughenour and Tweeten, 1986).

Hedonistic subindex: feelings of happiness or excitement with life. Reflects feelings (emotions) as opposed to cognitive (knowing, rational) dimensions of well-being. This subindex is represented by two indicator variables from General Social Surveys, 1972–1993 (Table 1).

Anomie subindex: lack of confidence in one's social environment. Anomie, a concept originating with Durkheim, 1951 to refer to normlessness, is characterized by feelings of fatalism, alienation, pessimism, and demoralization. Anomie is represented by six indicator variables from General Social Surveys, 1972–1993 (Table 1).

Confidence subindex: confidence in persons running institutions such as the educational system, government, business, labor unions, media, and the like. This subindex is represented by 14 indicator variables from General Social Surveys, 1972–1993 (Table 1).

Satisfaction subindex: degree of satisfaction with various aspects of life including family life, marriage, neighborhood, community (city), job, friendships, and the like. Six indicator variables forming this subindex are listed in Table 1.

It is apparent that perceived QL may differ from study to study depending on: (1) the subindices involved, (2) the indicator variables in each of the subindices, (3) method of aggregation, and (4) the sample of respondents. However, an earlier study (Tweeten and Mlay, 1986) found that the QLI was quite robust with respect to changes in domains and samples.

The concept of core utility may explain this consistency. At the turn of this century, Spearman, 1904 proposed and subsequent empirical data confirmed presence of core or general intelligence 'g' useful to predict outcomes under a range of circumstances. Factor analysis was used to identify this core intelligence quotient (IQ) from a set of written test items (indicator variables) administered to respondents. We presume that core quality of life (QOL) can be measured from responses to socio-psychological indicator variables weighted by the eigenvalues derived from factor analysis. To judge if weighting by eigenvalues is necessary in future studies, we compare results to those from unweighted indicator variables.

5. The creation of the QLI

The twenty-eight indicator variables shown in Table 1 are aggregated into a single dependent vari-

Table 1
Factor scores for all the indicator variables used in constructing the quality of life index

Indicator variables [a]	Factor number and eigenvalue (in parenthesis)					
	1 (4.4112)	2 (2.6876)	3 (1.7903)	4 (1.1704)	5 (1.1364)	6 (1.0211)
Hedonistic						
HAPPY	0.57524	0.03837	0.14475	0.12494	−0.01150	−0.24618
LIFE	0.49560	−0.15285	0.33217	0.02713	0.08128	−0.05717
Anomie 1						
HELPFUL	0.15449	0.06183	0.14279	0.68807	0.04299	−0.05843
FAIR	0.10002	0.10978	0.11736	0.73403	−0.01928	−0.07851
TRUST	0.12757	0.02971	0.23063	0.70774	−0.03522	0.02903
Anomie 2						
ANOMIA5	0.09117	0.07281	0.56551	0.20017	−0.16303	0.13016
ANOMIA6	0.15919	−0.04326	0.59163	0.23460	−0.15422	0.20486
ANOMIA7	0.01153	0.08299	0.57177	0.25090	0.11498	−0.09922
Confidence						
CONFINAN	0.08659	0.61682	−0.05157	0.11262	0.06953	0.11178
CONBUS	0.09083	0.50618	0.18051	0.14116	−0.00855	0.08497
CONCLERG	0.03050	0.46923	−0.05635	0.17144	0.04641	−0.11070
CONEDUC	0.02991	0.46457	0.10814	0.01171	0.21290	−0.09274
CONFED	0.03525	0.51934	0.42856	−0.07221	0.05433	−0.26948
CONLABOR	−0.01193	0.13274	0.06616	−0.11128	0.58429	−0.30935
CONPRESS	0.00553	0.05758	0.02685	0.05428	0.76528	0.20174
CONMEDIC	0.11284	0.48808	−0.00776	0.09485	0.20756	0.33840
CONTV	−0.02944	0.27845	−0.12362	0.03167	0.57914	0.10683
CONJUDGE	0.02433	0.41360	0.45707	−0.03834	0.22945	0.13599
CONSCI	0.09797	0.32762	0.30443	0.13928	0.12170	0.47612
CONLEGIS	0.03439	0.47567	0.40071	−0.08031	0.28275	−0.19837
CONARMY	0.05127	0.66846	0.00197	−0.12442	0.00216	−0.10562
GETAHEAD	0.10913	0.12404	−0.05829	0.16086	−0.00979	−0.41116
Satisfaction						
SATCITY	0.52879	0.14955	−0.00284	0.19534	−0.03941	−0.04148
SATHOBBY	0.66661	0.00305	0.07028	0.05286	−0.04376	0.19915
SATFAM	0.69063	0.08061	−0.07069	0.03479	0.01575	−0.01810
SATFRND	0.69698	0.07987	−0.05612	0.14580	0.01664	0.04044
SATHEALT	0.59400	0.06255	0.11588	−0.08204	0.00143	0.00468
SATJOB	0.34669	0.10157	0.05050	0.13970	−0.02067	−0.26667

Source: indicator variables defined and data in General Social Surveys.
[a] Only factors associated with eigenvalues greater than 1 are extracted.
Principle axis method: varimax rotation.

able, the QLI, using two methods: simple-summation and factor-weighted aggregation. The resulting QLI is then regressed on a group of explanatory variables including age, income, and education. The justification for the inclusion of the independent variables is discussed in the next section.

The data for this study are from personal interview surveys conducted in selected years from 1976 to 1990 (see Table 2) by the National Opinion Research Center (NORC), and described in the General Social Surveys, 1972–1993. Each survey was an independently drawn random sample of English-

Table 2
The number of people participating in each year of the survey

Year	Frequency	Percent	Cumulative frequency	Cumulative percent
76	1024	19.5	1024	19.5
80	1082	20.6	2106	40.0
84	752	14.3	2858	54.3
87	1330	25.3	4188	79.6
88	363	6.9	4551	86.5
89	394	7.5	4945	94.0
90	314	6.0	5259	100.0

Source: General Social Surveys.

Table 3
Definition of independent variables

Independent variable	Description
Income	Family income in 1986 constant dollars. Income is a continuous variable constructed from mid-range point estimates of 21 family income ranges.
Ageclass	10–19 years = 1 20–29 years = 2 80 + years = 8 No answer, don't know = 4
Prestige	Hodge, Seigel, Rossi prestige scale coded from 1 for lowest prestige occupation to 8 for highest prestige occupation.
Education	Highest grade completed, in actual years of schooling No answer, don't know = 8
Size	Size of place — This code is the population to the nearest 1,000 of the smallest civil division listed by the U.S. Census (city, town, other incorporated area over 1,000 in population, township, division, etc.)
Health	Would you say your own health in general, is excellent, good, fair or poor? Excellent = 1 Good = 2 Fair = 3 Poor = 4 Don't know, no answer = 2
Male	Dummy variable: Male = 1, Female = 0
Unemployed	Dummy variable: Unemployed = 1, Other = 0
Married	Dummy variable: Married = 1, Other = 0
Farmer	Dummy variable: Farmers (owner, operator, tenant, manager) and farm Laborers = 1 Others = 0
Family 16	Dummy variable: Were you living with both your own mother and your own father around the time you were 16? Yes = 1, No = 0
White	Dummy variable: A variable indicating race. White = 1, Others = 0
Household-size	Number of household members
East	Dummy variable: New England = 1 Middle Atlantic = 1 Other = 0
Midwest	Dummy variable: East North Central = 1 West North Central = 1 Other = 0
West	Dummy variable: Mountain = 1 Pacific = 1 Other = 0
South	Dummy variable: South Atlantic = 1 East South Central = 1 West South Central = 1 Other = 0
Rural	Dummy variable: Rural = 1, other = 0 (see classification below) — rural taken from Place Size = 9 or 10.
Size	(XNORCSIZE) — Coded from 1 to 10 with largest to smallest size of place of community residence. Central city of over 250,000 population = 1 Medium size central city of 50,000 to 250,000 = 2 ·●· ·●· ·●· An incorporated area less than 2,500 or an unincorporated area of 1,000 to 2,499 residents = 9 Open country within a larger civil division such as a township = 10

Table 3 (continued)

Independent variable	Description
Year 0–1 dummy variables	
1976	Dummy variable: 1976 = 1, Other = 0
1980	Dummy variable: 1980 = 1, Other = 0
1984	Dummy variable: 1984 = 1, Other = 0
1987	Dummy variable: 1987 = 1, Other = 0
1988	Dummy variable: 1988 = 1, Other = 0
1989	Dummy variable: 1989 = 1, Other = 0
1990	Dummy variable: 1990 = 1, Other = 0 (omitted in equation to avoid singularity)

Source: Data from the General Social Surveys.

speaking persons 18 years of age or over living in non-institutional arrangements within the continental US. Sample size is 5,259.

The component indicator variables used to construct the QLI are categorized under the domains defined in the previous section. Indicator variables were chosen for their conceptual relevance and their availability. The coding for each of the indicator variables is shown in General Social Surveys, 1972–1993 and Tweeten and Mlay, 1986. Factor analysis was used to construct a QLI from the indicator variables. The Statistical Analysis System (SAS) v. 6.13 package was used to perform the computations.

Table 1 shows the results of the factor analysis used to group indicator variables into a single QLI. If the subindices comprise distinct domains of the QOL, each factor in Table 1 will be uniquely and prominently identified with a subindex. The indicator variables associated with the Hedonistic and Satisfaction subindices load most heavily on Factor 1. The Anomie 1 and Anomie 2 subindices load heavily on Factor 4 and Factor 3, respectively.

The confidence subindex appears to be multidimensional because no one factor figures prominently for all indicator variables comprising the confidence subindex. For factor 2, weights are large for the indicator variables measuring confidence in financial institutions (CONFINAN), business (CONBUS), religion (CONCLERG), education (CONEDUC), the executive branch of the federal government (CONFED), medicine (CONMEDIC), the US Congress (CONLEGIS), and the military (CONARMY). The only variable prominent in factor 3 is confidence in the US Supreme Court (CONJUDGE). The indicator variables for confidence in labor (CONLABOR), confidence in the press (CONPRESS), and confidence in the TV media (CONTV) load most heavily into factor 5. The confidence in science (CONSCI) and the perception that one is getting ahead in life (GETAHEAD) weigh most heavily in factor 6. Only the six factors with eigenvalues exceeding 1.0 were included to ascertain the core QLI.

The QLI constructed from the results of the factor analysis in Table 1 is:

$$\mathrm{QLI} = \sum_{i=1}^{N} \sum_{j=1}^{M} w_j a_{ij} x_j \tag{9}$$

where: w_j = eigenvalue associated with factor j; a_{ij} = factor loading of indicator i in factor j; x_i = normalized indicator variable i, $x_i = (X_i - X_i)/s_i$ where the original observations X_i are adjusted for the estimated mean$_i$ and standard deviation s_i.

A common, alternative method of aggregating indicator variables is the simple summation:

$$\mathrm{QLI}' = \sum_{i=1}^{N} x_i. \tag{10}$$

Conceptually, the factor-weighted aggregation method shown in Eq. (9) is preferred. This method emphasizes indicator variables prominent in factors explaining the greatest proportions of overall variance in the indicator variables. Operationally, however, the simple-summation aggregation method shown in Eq. (10) is preferred for simplicity and convenience.

6. Justification for independent variable selection

Table 3 lists independent variables used to account for the variation in the dependent variable QLI

Table 4
Dependent and independent (non-dummy) variables used in the regression analysis

Variable	Mean	Standard deviation	Minimum	Maximum
Independent variables				
INCOME (US$)	32,387	25,315	483	128,159
INCOME^2 (US$)	1,689,658,895	2,733,210,748	233,289	16,424,729,281
AGECLASS	3.712	1.519	1	8
AGECLASS^2	16.091	13.009	1	64
PRESTIGE	3.551	1.482	1	8
EDUCATION	12.668	3.008	0	20
SIZE (000's)	392.031	1,277.13	0	7,895
HEALTH	1.889	0.797	1	4
Dependent variables				
QLI	156.410	41.369	0.01	273.3709773
QLI′	40.912	10.885	0.01	71.4114759

Source: Data from the General Social Surveys.
Note: Sample size is 5,259.
QLI is the factor weighted quality of life index.
QLI′ is the summation aggregated quality of life index.

or QLI′. Given that one of the major objectives of this study is to estimate the MUI, income becomes a primary variable used in explaining the variation of QLI and QLI′. Demographic variables are included as controls because of expected systematic differences in MU among individuals with different demographic characteristics (see Pollack and Wales, 1978).

The number of people in a household is used to control for possible household-size effects on the MUI. A larger household size would indicate the possibility that a given income is shared among several people. This would mean that a given level of income would generate a higher MUI for a person living in a large household. The number of people in a household is denoted by the variable household size. In addition, a household size by income interaction term is also included in the regressions.

An occupational prestige variable is included to control social standing arising from the practice of a particular occupation. The absence of the prestige variable could confound the influence of income with prestige; hence biasing the coefficients of the income variable in the QLI equation.

An alternative approach would be to measure the MU of wealth (net worth) rather than income. Data on human and material wealth of respondents participating in the General Social Surveys are not available. However, income is a useful proxy because it is the flow from the stock of wealth and is perfectly correlated with wealth if rates of return on wealth are equal for all respondents.

7. Econometric analysis and results

Econometric analysis is performed to determine the contribution of independent variables to variation in the QLI. Several functional forms are used to satisfy alternative concepts of how utility is influenced by changes in income. In addition, the factor-weighted QLI and simple-summation weighted QLI′ are alternatively used as dependent variables to determine if the econometric results are invariant with respect to the construction of the QLI.

The functional forms investigated are the quadratic, Cobb-Douglas, square root and semilog equations. These are shown, respectively, as follows (See Table 3 for variable definitions):

$$\begin{aligned}\text{QLI} = {} & \beta_0 + \beta_1 \text{ Income} + \beta_2 \text{ Income}^2 \\ & + \beta_3 \text{ Ageclass} + \beta_4 \text{ Ageclass}^2 \\ & + \beta_5 \text{ Prestige} + \beta_6 \text{ Education} \\ & + \beta_7 \text{ Size} + \beta_8 \text{ Farmer} \times \text{Income} \\ & + \beta_9 \text{ Household} - \text{size} + \beta_{10} \text{ Household} \\ & - \text{size} \times \text{Income} + \Sigma \delta_i X_i \qquad (11)\end{aligned}$$

Table 5
The influence of selected variables on the quality of life index: ordinary least squares estimates of the quadratic function using weighted factor aggregation and summation weighted aggregation with normalized variables

Variable	Parameter estimate	Standard error	T for HO: parameter = 0	Prob > $\|T\|$	Standardized estimate
Weighted factor aggregation (QLI dependent)					
INTERCEPT	149.152994	4.65804476	32.021	0.0001	0.00000000
INCOME	0.000275	0.00007409	3.709	0.0002	0.16816109
INCOME^2	−1.4274E-9	0.00000000	−2.233	0.0256	−0.09430771
AGE	−5.909120	1.82943510	−3.230	0.0012	−0.21707100
AGE^2	0.922668	0.21440042	4.303	0.0001	0.29014865
PRESTIGE	1.596376	0.44320487	3.602	0.0003	0.05719432
EDUCATION	1.068678	0.23222243	4.602	0.0001	0.07771690
SIZE	−0.001898	0.00042389	−4.477	0.0001	−0.05859022
HEALTH	−11.893027	0.72125723	−16.489	0.0001	−0.22933398
MALE	−2.216301	1.09787109	−2.019	0.0436	−0.02658955
UNEMPLOYED	−8.118515	3.49520767	−2.323	0.0202	−0.03024418
MARRIED	4.457590	1.21203021	3.678	0.0002	0.05266899
WHITE	10.270934	1.51609757	6.775	0.0001	0.09293425
FAMILY16	3.516123	1.26219567	2.786	0.0054	0.03686486
WEST	−4.509188	1.38679244	−3.252	0.0012	−0.04226182
R^2 0.1391	Adjusted R^2	0.1368	C.V. 24.57376		
Summation weighted aggregation (QLI′ dependent)					
INTERCEPT	38.488358	1.21560006	31.662	0.0001	0.00000000
INCOME	0.000077	0.00001933	4.019	0.0001	0.18073064
INCOME^2	−3.923E-10	0.00000000	−2.352	0.0187	−0.09852212
AGE	−1.503763	0.47742380	−3.150	0.0016	−0.20993324
AGE^2	0.241841	0.05595162	4.322	0.0001	0.28902024
PRESTIGE	0.431090	0.11566223	3.727	0.0002	0.05869595
EDUCATION	0.296705	0.06060260	4.896	0.0001	0.08200044
SIZE	−0.000532	0.00011062	−4.807	0.0001	−0.06238441
HEALTH	−3.226799	0.18822497	−17.143	0.0001	−0.23646718
MALE	−0.692745	0.28650909	−2.418	0.0156	−0.03158481
UNEMPLOYED	−2.257612	0.91213693	−2.475	0.0134	−0.03196226
MARRIED	1.259883	0.31630095	3.983	0.0001	0.05657284
WHITE	2.876166	0.39565277	7.269	0.0001	0.09890146
FAMILY16	0.961970	0.32939253	2.920	0.0035	0.03832948
WEST	−1.290140	0.36190828	−3.565	0.0004	−0.04595253
R^2 0.1532	Adjusted R^2	0.1509	C.V. 24.51703		

$$\mathrm{QLI} = \exp(\beta 0 \times \mathrm{Income}^{\beta 1} \times \mathrm{Ageclass}^{\beta 2} \times \mathrm{Prestige}^{\beta 3} \times \mathrm{Education}^{\beta 4} \times \mathrm{Size}^{\beta 5} \times \mathrm{Household-size}^{\beta 6}) \times \exp(\Sigma\delta_i X_i) \quad (12)$$

$$\mathrm{QLI} = \beta_0 + \beta_1\ \mathrm{Income} + \beta_2\ \mathrm{Income}^{0.5} + \beta_3\ \mathrm{Ageclass} + \beta_4\ \mathrm{Ageclass}^2 + \beta_5\ \mathrm{Prestige} + \beta_6\ \mathrm{Education} + \beta_7\ \mathrm{Size} + \beta_8\ \mathrm{Farmer} \times \mathrm{Income} + \beta_9\ \mathrm{Household-size} + \beta_{10}\ \mathrm{Household-size} \times \mathrm{Income} + \Sigma\delta_i X_i \quad (13)$$

$$\mathrm{QLI} = \beta_0 + \beta_1 \ln(\mathrm{Income}) + \beta_2\ \mathrm{Income}^2 + \beta_3\ \mathrm{Ageclass} + \beta_4\ \mathrm{Ageclass}^2 + \beta_5\ \mathrm{Prestige} + \beta_6\ \mathrm{Education} + \beta_7\ \mathrm{Size} + \beta_8\ \mathrm{Farmer} \times \mathrm{Income} + \beta_9\ \mathrm{Household-size} + \beta_{10}\ \mathrm{Household-size} \times \mathrm{Income} + \Sigma\delta_i X_i \quad (14)$$

Here

$$\Sigma\delta_i X_i = \delta_1\ \mathrm{Health} + \delta_2\ \mathrm{Male} + \delta_3\ \mathrm{Unemployed} + \delta_4\ \mathrm{Married} + \delta_5\ \mathrm{Farmer} + \delta_6\ \mathrm{White} + \delta_7\ \mathrm{Family16} + \delta_8\ \mathrm{East} + \delta_9\ \mathrm{Midwest}$$

Table 6
The influence of selected variables on the quality of life index: ordinary least squares estimates of the Cobb Douglas function using weighted factor aggregation and summation weighted aggregation with normalized variables

Variable	Parameter estimate	Standard error	T for HO: parameter = 0	Prob > $\|T\|$	Standardized estimate
Weighted factor aggregation (QLI dependent)					
INTERCEPT	4.736970	0.05982221	79.184	0.0001	0.00000000
LN(INCOME)	0.029674	0.00604629	4.908	0.0001	0.07689963
LN(AGE)	0.025979	0.01118376	2.323	0.0202	0.03162653
LN(PRESTIGE)	0.045810	0.00984762	4.652	0.0001	0.06634941
LN(SIZE)	−0.004845	0.00189275	−2.560	0.0105	−0.03546663
HEALTH	−0.095489	0.00606115	−15.754	0.0001	−0.22120842
MALE	−0.022343	0.00931075	−2.400	0.0164	−0.03220334
UNEMPLOYED	−0.062991	0.02967644	−2.123	0.0338	−0.02819173
MARRIED	0.019595	0.01018935	1.923	0.0545	0.02781486
WHITE	0.082895	0.01301691	6.368	0.0001	0.09010911
FAMILY16	0.025896	0.01068767	2.423	0.0154	0.03261731
WEST	−0.025452	0.01180052	−2.157	0.0311	−0.02865842
R^2 0.1027	Adjusted R^2	0.1008	C.V. 6.51959		
Summation weighted aggregation (QLI′ dependent)					
INTERCEPT	3.357402	0.05808167	57.805	0.0001	0.00000000
LN(INCOME)	0.033225	0.00587038	5.660	0.0001	0.08792503
LN(AGE)	0.029604	0.01085836	2.726	0.0064	0.03680250
LN(PRESTIGE)	0.046582	0.00956110	4.872	0.0001	0.06889473
LN(SIZE)	−0.005506	0.00183768	−2.996	0.0027	−0.04115218
HEALTH	−0.098338	0.00588480	−16.711	0.0001	−0.23263090
MALE	−0.025116	0.00903985	−2.778	0.0055	−0.03696545
UNEMPLOYED	−0.066122	0.02881300	−2.295	0.0218	−0.03021908
MARRIED	0.021992	0.00989289	2.223	0.0263	0.03187834
WHITE	0.087085	0.01263818	6.891	0.0001	0.09666662
FAMILY16	0.027641	0.01037671	2.664	0.0078	0.03555301
WEST	−0.026339	0.01145718	−2.299	0.0215	−0.03028434
R^2 0.1180	Adjusted R^2	0.1162	C.V. 8.64502		

$$+ \delta_{10}\ \text{West} + \delta_{11}\ \text{Rural} + \delta_{12}\ 1976 + \delta_{13}\ 1980 + \delta_{14}\ 1984 + \delta_{15}\ 1987 + \delta_{16}\ 1988 + \delta_{17}\ 1989$$

To reduce multi-collinearity, variables having non-significant parameters in the models are dropped and the equations are re-estimated. Table 4 includes descriptive statistics of the variables.

The results of the four functional forms using the factor-weighted quality of life indices, QLI and QLI′, are shown in Tables 5–8. For all models, the adjusted R^2 ranges from 0.101 to 0.151. These R^2 values are typical for cross-section studies explaining variation in attitudes among individuals. Models using a simple summation-weighted QLI as a dependent variable have slightly higher adjusted R^2 values. Simple aggregation appears to give satisfactory results. However, normalizing variables about the zero mean and unit variance is recommended as done for all results in this study.

Coefficients of income, prestige, age, size, gender, employment status, marital status, race, being raised by both a mother and father, residence in the West, and health are significant for all functional forms (Tables 5–8). Restricted F-tests indicate that variables dropped from the initial specification to reduce multi-collinearity do not, in aggregate, significantly influence variation in the QLI [1]. For all models, the insignificance of coefficients for the year dummy variables indicates that QLI and QLI′ are invariant over time. Residence on a farm, in a rural area, and in a specific geographic region (except the

[1] The results from the restricted F-tests are not presented herein but are available from the authors.

Table 7
The influence of selected variables on the quality of life index (QLI): ordinary least squares estimates of the square root function using weighted factor aggregation and summation weighted aggregation with normalized variables

Variable	Parameter estimate	Standard error	T for HO: parameter = 0	Prob > $\|T\|$	Standardized estimate
Weighted factor aggregation (QLI dependent)					
INTERCEPT	145.032914	5.20845663	27.846	0.0001	0.00000000
INCOME	−0.000062	0.00009165	−0.677	0.4982	−0.03799169
$\text{INCOME}^{0.5}$	0.074673	0.03644028	2.049	0.0405	0.12023442
AGE	−5.853135	1.82850355	−3.201	0.0014	−0.21501440
AGE^2	0.917313	0.21436258	4.279	0.0001	0.28846468
PRESTIGE	1.608860	0.44301518	3.632	0.0003	0.05764157
EDUCATION	1.067995	0.23238880	4.596	0.0001	0.07766723
SIZE	−0.001910	0.00042417	−4.502	0.0001	−0.05895830
HEALTH	−11.890656	0.72166771	−16.477	0.0001	−0.22928824
MALE	−2.219367	1.09848474	−2.020	0.0434	−0.02662634
UNEMPLOYED	−8.013742	3.50091999	−2.289	0.0221	−0.02985387
MARRIED	4.460303	1.21733761	3.664	0.0003	0.05270104
WHITE	10.228901	1.51945482	6.732	0.0001	0.09255392
FAMILY16	3.525806	1.26224651	2.793	0.0052	0.03696638
WEST	−4.495356	1.38681667	−3.241	0.0012	−0.04213218
R^2 0.1390	Adjusted R^2	0.1367	C.V. 24.5756		
Summation weighted aggregation (QLI′ dependent)					
INTERCEPT	37.292330	1.35919180	27.437	0.0001	0.00000000
INCOME	−0.000017	0.00002392	−0.722	0.4701	−0.04017556
$\text{INCOME}^{0.5}$	0.021511	0.00950941	2.262	0.0237	0.13162652
AGE	−1.492880	0.47716381	−3.129	0.0018	−0.20841404
AGE^2	0.240993	0.05593977	4.308	0.0001	0.28800678
PRESTIGE	0.433685	0.11560864	3.751	0.0002	0.05904932
EDUCATION	0.295998	0.06064387	4.881	0.0001	0.08180496
SIZE	−0.000536	0.00011069	−4.838	0.0001	−0.06282846
HEALTH	−3.224763	0.18832543	−17.123	0.0001	−0.23631795
MALE	−0.695705	0.28665909	−2.427	0.0153	−0.03171977
UNEMPLOYED	−2.220670	0.91359535	−2.431	0.0151	−0.03143925
MARRIED	1.252787	0.31767478	3.944	0.0001	0.05625422
WHITE	2.860094	0.39651488	7.213	0.0001	0.09834882
FAMILY16	0.963756	0.32939414	2.926	0.0034	0.03840065
WEST	−1.286994	0.36190180	−3.556	0.0004	−0.04584050
R^2 0.1531	Adjusted R^2	0.1509	C.V. 24.5180		

West) also had no statistically significant impact on QLI, other things equal. In addition, the household-size variable, either alone or interacting with income, has no statistically significant impact on the quality of life.

Other things being equal, respondents with little education, raised in a single parent family in a small place (city), and in poor health have a lower overall QLI. In addition, being a male, a nonwhite person, living in the West, and single are associated with a lower overall QLI. Results in Table 5 indicate that QLI initially falls and then rises with increasing age, the lowest QLI occurring in the 30–39 age range.

Judging by the standardized regression coefficients, income, age, and health have the greatest impact on the QLI. Each standard deviation improvement in the health variable raises the QLI by 0.23 standard deviations according to the results in Table 5. An increase in occupational prestige and income raises perceived QLI. The increase in QLI and QLI′ as income increases is not constant as demonstrated by the significant INCOME^2 coefficient. QLI and QLI′ increase as income increases but at a decreasing rate, consistent with declining MUI. The similar standardized parameter estimates for QLI or QLI′ suggest that it does not matter which weighting

Table 8
The influence of selected variables on the quality of life index: ordinary least squares estimates of the semilog function using weighted factor aggregation and summation weighted aggregation with normalized variables

Variable	Parameter estimate	Standard error	T for HO: parameter = 0	Prob > $\lvert T\rvert$	Standardized estimate
Weighted factor aggregation (QLI dependent)					
INTERCEPT	118.155259	7.33013124	16.119	0.0001	0.00000000
LN(INCOME)	3.612879	0.73920554	4.888	0.0001	0.07793450
AGE	−5.654804	1.82524308	−3.098	0.0020	−0.20772873
AGE^2	0.898106	0.21395867	4.198	0.0001	0.28242467
PRESTIGE	1.649032	0.44258425	3.726	0.0002	0.05908083
EDUCATION	1.100030	0.23181120	4.745	0.0001	0.07999690
SIZE	−0.001928	0.00042413	−4.545	0.0001	−0.05950526
HEALTH	−11.925238	0.72150821	−16.528	0.0001	−0.22995509
MALE	−2.154508	1.09802663	−1.962	0.0498	−0.02584820
UNEMPLOYED	−7.827355	3.49799758	−2.238	0.0253	−0.02915951
MARRIED	4.557421	1.20981363	3.767	0.0002	0.05384855
WHITE	10.208802	1.51837278	6.724	0.0001	0.09237206
FAMILY16	3.556571	1.26236586	2.817	0.0049	0.03728893
WEST	−4.482842	1.38703202	−3.232	0.0012	−0.04201489
R^2 0.1384	Adjusted R^2	0.1362	C.V. 24.5814		
Summation weighted aggregation (QLI′ dependent)					
INTERCEPT	29.365617	1.91296517	15.351	0.0001	0.00000000
LN(INCOME)	1.062073	0.19291257	5.505	0.0001	0.08706703
AGE	−1.437613	0.47633887	−3.018	0.0026	−0.20069836
AGE^2	0.235736	0.05583740	4.222	0.0001	0.28172411
PRESTIGE	0.444891	0.11550247	3.852	0.0001	0.06057508
EDUCATION	0.305005	0.06049643	5.042	0.0001	0.08429436
SIZE	−0.000541	0.00011069	−4.887	0.0001	−0.06346821
HEALTH	−3.234030	0.18829405	−17.175	0.0001	−0.23699709
MALE	−0.678034	0.28655513	−2.366	0.0180	−0.03091410
UNEMPLOYED	−2.161790	0.91288236	−2.368	0.0179	−0.03060566
MARRIED	1.276751	0.31572850	4.044	0.0001	0.05733026
WHITE	2.851686	0.39625406	7.197	0.0001	0.09805970
FAMILY16	0.972253	0.32944320	2.951	0.0032	0.03873920
WEST	−1.283666	0.36197768	−3.546	0.0004	−0.04572196
R^2 0.1525	Adjusted R^2	0.1504	C.V. 24.52515		

method for QLI is used. However, the use of factor-weighted aggregation is recommended in subsequent studies if indicator variables other than those in this study are used. Identifying the relationship of the indicator variable components to overall QLI can be important and assisted by factor analysis.

8. Evaluation of MU

How the perceived QLI changes as income increases is of special importance in this study. For convenience, the marginal response of the quality of life index to income (dQLI/dincome) is the MUI, However, we recognize that MUI is a proxy, an empirical manifestation of an unobservable response of actual utility to changes in income. Estimated parameters from Eqs. (11)–(14) and their associated test statistics are reported in Tables 6–9, respectively.

The quadratic QLI function (Eq. (11) and Table 5) exhibits a linear MU curve as apparent from the following first-order equations:

$$\mathrm{MUI(QLI)} = 0.000275 - 2.8548 \times 10^{-9}\ \mathrm{Income} \tag{15}$$

Table 9
Marginal utility as proportion of MUI at mean income for alternative income levels

Functional form	Income as proportion of mean income						
	0.10 (US$3,239)	0.25 (US$8,097)	0.50 (US$16,194)	1.00 (US$32,387)	2.00 (US$64,774)	4.00 (US$129,548)	10.00 (US$323,870)
Quadratic	1.46	1.38	1.25	1.00	0.49	−0.52	−3.56
Cobb-Douglas	9.40	3.52	1.88	1.00	0.53	0.28	0.12
Square root	4.08	2.42	1.59	1.00	0.58	0.29	0.03
Semilog	10.00	4.00	2.00	1.00	0.50	0.25	0.10

$$\mathrm{MUI(QLI')} = 0.000077 - 7.8460 \times 10^{-10}\ \mathrm{Income} \quad (16)$$

The quadratic equations indicate a point at which additional income does not add to the quality of life. Solving the above equations for income where MUI = 0, the results are US$96,328 for Eq. (15) and US$98,139 for Eq. (16). When graphed, the MUI lines from Eqs. (11)–(14) and Tables 5–8 for factor-weighted and summation-weighted aggregations are almost indistinguishable from each other. Because the behavior of MU is slightly influenced by the method of aggregation, only results for the factor-weighted regressions are shown in Figs. 1–4. For convenience, the first order equations are normalized to MUI = 1.0 at the US mean family income (US$32,387: 1986 dollars). Income expressed as a proportion of mean income is graphed on the horizontal axis.

The quadratic form shown in Fig. 1 has limitations. Revealed preference theory postulates that people prefer more to less at all income levels, hence MU does not become negative as income becomes large. The persistent effort of affluent individuals to seek even higher income is further, albeit circumstantial, evidence that the MUI is not negative. We would expect the absolute risk coefficient to decrease, not increase (as implied by the quadratic function) as income becomes large.

Figs. 2–4 show MUI for the Cobb-Douglas, square root, and semilog equations, respectively. MUI derived from these equations are curvilinear but to varying degrees. Table 9 shows MUI at various income levels for the four functional forms. At higher income, MUI is less for the square root function than for the Cobb-Douglas and semilog equations but is more than for the quadratic function. For measuring MUI at higher income levels, the square root function is preferred to the quadratic on conceptual grounds and slightly preferred to the Cobb-Douglas and semilog functions on goodness-of-fit grounds.

The concept of core utility may explain this con-

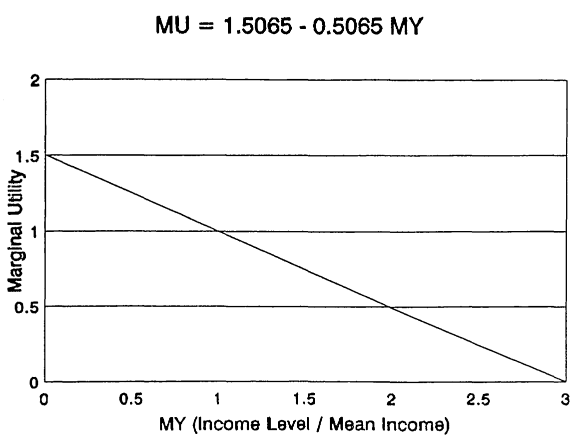

Fig. 1. The marginal utility curve for the quadratic function.

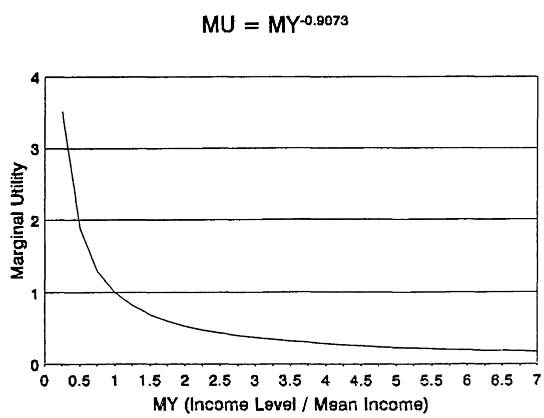

Fig. 2. The marginal utility curve for the Cobb-Douglas function.

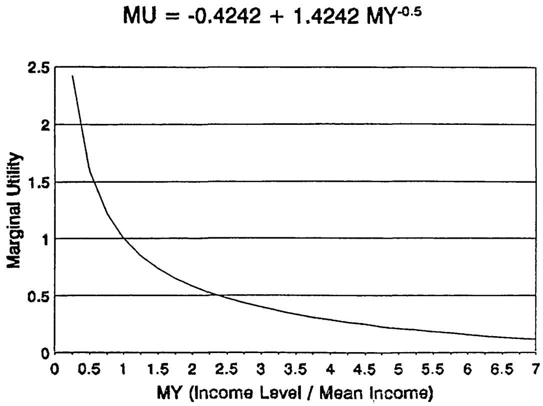

Fig. 3. The marginal utility curve for the square root function.

sistency. Spearman, 1904 proposed, confirmed by subsequent empirical studies, the presence of core human intelligence element called 'g' that generalized to predict outcomes in a wide range of circumstances apart from unique abilities to perform specific tasks. Factor analysis could measure this core general intelligence by weighting a set of responses to written items (indicator variables) administered to respondents. We presume core utility can also be gleamed from responses to socio-psychological indicator variables designed to solicit the individual's state of well-being. Factor analysis eigenvalues are presumed to measure weights of those indicator variables contributing most to general utility. In recognition of the controversial use of eigenvalues to weight indicator variables, we also compare results from unweighted indicator variables.

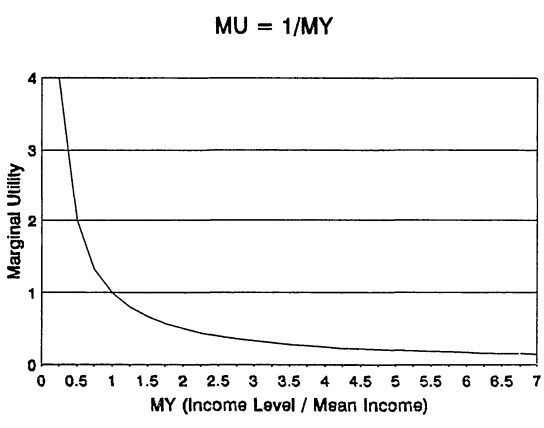

Fig. 4. The marginal utility curve for the semilog function.

The curvilinear functional forms indicate that MUI approaches infinity as income approaches zero. This high MUI can pose problems in empirical applications when weighing benefits and costs to very low income people. The MUI derived from the quadratic function has a finite value (1.5) at zero income. We prefer it (Fig. 1) to the curvilinear specifications (Figs. 2–4) for measuring MUI at low income levels, but analysts are free to choose from the alternative MU specification in Figs. 1–4.

9. Conclusion

A QLI, a proxy measure of utility, is constructed by factor-weighted and simple-summation weighted aggregation of socio-psychological measures of well-being. The socio-psychological measures were constructed from QOL domains taken from selected years of the General Social Surveys, 1972–1993. The QLIs are regressed on income, age, health, and other selected socio-demographic variables using quadratic, Cobb-Douglas, square root, and semilog functional forms.

Regardless of functional form tested and the method of aggregation used to construct the QLI, income, age, and health have the greatest impact on the QLI. The QLI is not influenced by the year in which it is measured, suggesting that it is temporally stable. QLI as measured here is not much influenced by farm, rural, or regional residence or by household size. The method of aggregation used to construct the QLI does not greatly influence the magnitude of the selected independent variables on the quality of life. However, normalization of indicator variables to mean zero and variance 1.0 is recommended.

The quadratic function showed the best fit in explaining the variability of the QLI. The low R^2 values found herein are not unusual and indicate that much variability in the QLI is unique to individuals and that our results are better suited to predict group, rather than individual well-being.

The quadratic function has the best fit as measured by R^2, but is theoretically implausible for high income levels. The Cobb-Douglas, square root, and semilog functions show theoretically plausible MUI curves for higher income levels but implausibly assume infinite utility from the first unit of income. The degree of MUI decline in response to increased income levels is greatest for the square root function and is smallest for the Cobb-Douglas function. Measured by goodness of fit (excluding the quadratic), the square root function is slightly preferred to measure MUI at higher income levels. It is also attractive in ranking between the level of MUI predicted by the quadratic function on the one hand, and the Cobb-Douglas and semilog functions on the other hand. One option for practitioners computing the benefit–cost ratio for a public program, project, or policy using results of this study is to weight dollars by income groups with MUIs from the quadratic function for income below the mean and from the square root function for income above the mean.

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