A Two-Constraint AIDS Model of Recreation Demand

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Presented at Western Agricultural Economics Association 1997 Annual Meeting
July 13-16, 1997
Reno/Sparks, Nevada

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Proposed Running Head:
“Two-Constraint AIDS Model"

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Abstract

An AIDS-based model of recreation, donation, and other goods allocation subject to money and time constraints is developed, and the resulting two share systems are jointly estimated. Applied to California whalewatching and donations activites, the model has significant own-price, cross- price, and budget effects in both share systems.

A Two-Constraint AIDS Model of Recreation Demand

Two important issues in the literature on recreation demand are the treatment of time constraints and substitution effects. The importance of time "prices" of recreation activities has been recognized since the earliest studies by Clawson (1959) and Knetsch (1963), because of its influence (in particular, the effect of its omission) on the money price coefficients of recreation demand equations and the resulting benefit estimates. Some recent literature has begun to model recreation choice subject to both money and time constraints (Smith; McConnell and Strand; Bockstael et al.). Often the approach is to assume the marginal money value of time is an exogenous parameter such as the wage rate or some fraction thereof (e.g., Cesario; Smith et al.; McConnell and Strand); while appropriate for those who are trading time for money at the margin, this may either understate or overstate the marginal value of leisure time for those with fixed hours worked (Bockstael et al.).

Substitution effects are similarly important for recreation demand analysis. Often substitutes are not modelled at all due to the difficulty of identifying the relevant choice sets. With spatially separated consumers, the choice sets will often vary across the data sample. Where they have been implemented in empirical models, substitutes often take the form of alternative recreation sites which also support the recreation activity being modelled (e.g., Burt and Brewer.)

This paper attempts to address the modelling of time constraints and substitution effects with a somewhat different approach. A two-constraint demand system is constructed based on the Almost Ideal Demand System (AIDS) approach of Deaton and Muellbauer. Because choice is subject to two constraints, the model has two expenditure functions, one minimizing money expenditure subject to utility and time constraints, the other minimizing time expenditure subject to utility and money constraints. This gives rise to two share systems, one for money and time expenditure, and utility maximization implies cross-system as well as within-system parameter restrictions. A parameter in the model (ρ) represents the elasticity of compensated money expenditure with respect to time budget, and can be rearranged to give the marginal value of time which varies across individuals.

The model is applied to recreational whalewatching in California. The treatment of substitutes in the demand system differs from most past treatments. The substitute goods in the the demand share systems are trips taken to go recreational whalewatching and donations made by individuals of time and money related to whales and marine mammals. This leads to estimates of the demand for contributions of money and time. While results obtained to date are highly preliminary, the estimated relationships are highly significant with signs largely consistent with theoretical expectations. They suggest interesting substitution patterns among goods related to whales, and suggest possibilities for measuring the consumer's surplus associated with giving, or "warm glow."

The Model

The focus of our analysis is on individuals at corner solutions in the labor market, who have fixed work hours. The presence of such rigidities prevents equilibration of the money value of time across all uses, as do the large variety of other temporal constraints that most consumers face with respect to the uses of their discretionary time (Smith et al.). Thus the wage does not necessarily reveal anything about the shadow value of discretionary leisure time, either as an upper or lower bound (Bockstael et al.).

Consider this individual's choice problem concerning the allocation of discretionary time remaining after, and income generated from, the fixed hours worked. This choice problem is thus completely independent of the labor supply choice, and the shadow value of leisure time is independent of the labor wage. Let $\mathbf{x}$ be a vector of consumption goods with corresponding money prices $\mathbf{p}$ and time prices $\mathbf{t}$, and choices are made subject to a money budget constraint $M \geq \mathbf{px}$ and a strictly binding time constraint $T = \mathbf{tx}$. Intuitively, the reason the time constraint always binds is that time must always be "spent" in some activity, whereas it is possible (though unlikely) that the income constraint will not bind, indicating satiation. As special cases, some of the elements of $\mathbf{t}$ or $\mathbf{p}$ could be zero, indicating activities that require time but no money (such as walks on the beach) or money but no–or little–time, such as making charitable contributions. The individual's utility is also influenced by an exogenous nonpriced quality variable z.

The primal version of the problem[1] leads to the indirect utility function v(**p**,**t**,z,M,T), defined as

$$v(\mathbf{p}, \mathbf{t}, z, M, T) \equiv \max_{\mathbf{x}} u(\mathbf{x}, z) + \lambda\{M - \mathbf{px}\} + \mu\{T - \mathbf{tx}\}$$

where the ratio of the Lagrange multipliers on the time and money constraints, $\mu / \lambda = [\partial v(\cdot) / \partial T] / [\partial v(\cdot) / \partial M]$, indicates the money value of time. Note that in the case where the money budget is slack, the marginal value of time goes infinite. Because the time constraint holds as an identity, the marginal utility of time can have any sign and the marginal value of discretionary time can be positive or negative.

The dual money dual expenditure function e(**p**,**t**,z,T,u) is defined as

$$e(\mathbf{p}, \mathbf{t}, z, T, u) \equiv \min_{\mathbf{x}} \mathbf{px} \text{ s.t. } T = \mathbf{tx},\ u = u(\mathbf{x}, z)$$

and the dual time expenditure function is defined as

$$\xi(\mathbf{p}, \mathbf{t}, z, M, u) \equiv \min_{\mathbf{x}} \mathbf{tx} \text{ s.t. } M \geq \mathbf{px},\ u = u(\mathbf{x}, z)$$

The marginal value of time can be expressed in terms of each of these dual functions as $[\partial e(\cdot) / \partial T]$ and $[\partial \xi(\cdot) / \partial M]^{-1}$ as will be verified in the empirical specification below.

The empirical specification of the two-constraint model is developed based on the AIDS expenditure function with demographic shifters and corresponding share equations. Beginning with any one of the optimized choice functions v(·), e(·), or ξ(·), one can derive the others from the dual structure of the optimization problem. It is most convenient to

[1] See Smith (1986) for a thorough discussion of the dual properties of the two-constraint recreation demand model.

develop the dual structure in terms of the money cost function, following the development of the standard AIDS model. Let the log-money expenditure function be

$$(1)\qquad \begin{aligned} \log e(\mathbf{p},\mathbf{t},z,T,u) &= \alpha_0 + \sum_i [\alpha_i + \gamma_i \log(z)]\cdot\log(p_i) - \rho\sum_i[\sigma_i + \theta_i \log(z)]\cdot\log(t_i) \\ &+ \frac{1}{2}\left\{\sum_i\sum_j[\gamma_{ij} + \varepsilon_{ij}\log(z)]\cdot\log(p_i)\log(p_j) - \rho\sum_i\sum_j[\phi_{ij} + \tau_{ij}\log(z)]\cdot\log(t_i)\log(t_j)\right\} \\ &+ \rho\sum_i\sum_j[\delta_{ij} + \psi_{ij}\log(z)]\cdot\log(p_i)\log(t_j) + \rho\log(T) + u\beta_0\prod_i p_i^{\beta_i} t_i^{\psi_i} \end{aligned}$$

where $\rho = \partial \log e(\cdot) / \partial \log T) = [\partial e(\cdot) / \partial(T)](T / M)$ is the elasticity of compensated money expenditure with respect to the time budget. This parameter, which has units (dollars/time), converts all the time-denominated arguments of the money expenditure function into money terms.

Now the utility dual of the money expenditure function, obtained by inverting e(**p**,**t**,z,T,u) with respect to the utility argument, is the indirect utility function

$$(2)\qquad \begin{aligned} v(\mathbf{p},\mathbf{t},z,M,T) = \Bigg\{ &[\log M - \rho\log T] - \alpha_0 - \sum_i[\alpha_i + \gamma_i\log(z)]\cdot\log(p_i) + \rho\sum_i[\sigma_i + \theta_i\log(z)] \\ &\cdot\log(t_i) - \left\{\frac{1}{2}\sum_i\sum_j[\gamma_{ij} + \varepsilon_{ij}\log(z)]\cdot\log(p_i)\log(p_j) - \rho\sum_i\sum_j[\phi_{ij} + \tau_{ij}\log(z)]\cdot\log(t_i)\log(t_j)\right\} \\ &- \rho\sum_i\sum_j[\delta_{ij} + \psi_{ij}\log(z)]\cdot\log(p_i)\log(t_j)\Bigg\}\cdot\beta_0^{-1}\prod_i p_i^{-\beta_i} t_i^{-\psi_i} \end{aligned}$$

Equation (2) makes the role of the parameter ρ plain: it is the ratio of the separate effects of the log budgets on the individual's utility level. All other parameters of the indirect utility function can be considered to be normalized on the coefficient of log money income.

The time expenditure function, obtained by inverting v(**p**,**t**,z,M,T) with respect to T, is

$$
\begin{aligned}
\log\xi(\mathbf{p},\mathbf{t},\mathrm{z},\mathrm{T},\mathrm{u}) = -\frac{1}{\rho}\Bigg\{&\alpha_0+\sum_i[\alpha_i+\gamma_i\log(\mathrm{z})]\cdot\log(\mathrm{p}_i)-\rho\sum_i[\sigma_i+\theta_i\log(\mathrm{z})]\cdot\log(\mathrm{t}_i)\\
&+\frac{1}{2}\left\{\sum_i\sum_j[\gamma_{ij}+\varepsilon_{ij}\log(\mathrm{z})]\cdot\log(\mathrm{p}_i)\log(\mathrm{p}_j)-\rho\sum_i\sum_j[\phi_{ij}+\tau_{ij}\log(\mathrm{z})]\cdot\log(\mathrm{t}_i)\log(\mathrm{t}_j)\right\}\\
&+\rho\sum_i\sum_j[\delta_{ij}+\psi_{ij}\log(\mathrm{z})]\cdot\log(\mathrm{p}_i)\log(\mathrm{t}_j)-\log(\mathrm{M})+\mathrm{u}\beta_0\prod_i\mathrm{p}_i^{\beta_i}\mathrm{t}_i^{\psi_i}\Bigg\}
\end{aligned}
\tag{3}
$$

The marginal value of time can be seen from (2) to be $[\partial\mathrm{v}(\cdot)/\partial\mathrm{T}]/[\partial\mathrm{v}(\cdot)/\partial\mathrm{M}]=-\rho\mathrm{M}/\mathrm{T}$. In (1), this is $\partial\mathrm{e}(\cdot)/\partial\mathrm{T}=-\rho\mathrm{M}/\mathrm{T}$, and in (3) the equivalent expression is $[\partial\xi(\cdot)/\partial\mathrm{M}]^{-1}=-\rho\mathrm{M}/\mathrm{T}$, as noted above.

The Systems of Money Share and Time Share Equations

The Hicksian (utility constant) money share equations come from differentiating (1) with respect to money prices; solving (2) for the utility index and substituting this into the Hicksian share equations yields the Marshallian money share equations, which are of the form

$$
\begin{aligned}
\mathrm{w}_i(\mathbf{p},\mathbf{t},\mathrm{z},\mathrm{M},\mathrm{T}) = {}&\alpha_i+\gamma_i\log(\mathrm{z})+\sum_j[\gamma^*_{ij}+\varepsilon^*_{ij}\log(\mathrm{z})]\cdot\log(\mathrm{p}_j)+\rho\sum_j[\delta^*_{ij}+\psi^*_{ij}\log(\mathrm{z})]\cdot\log(\mathrm{t}_j)\\
&+\beta_i\log(\mathrm{M}/\mathrm{MI})-\rho\beta_i\log(\mathrm{T}/\mathrm{TI})
\end{aligned}
\tag{4}
$$

where $\gamma^*_{ij}=½(\gamma_{ij}+\gamma_{ji})$ under symmetry, and ε^*_{ij}, δ^*_{ij}, and Ψ^*_{ij} are defined similarly.

The money income and time budget deflators are MI and TI, respectively.[2]

Time share equations are derived analogously, noting that by the envelope theorem Hicksian time share equations come from differentiating (3) with respect to t_i.. Again substituting the utility index, the Marshallian time share equations are

$$\omega_i(\mathbf{p},\mathbf{t},z,M,T)=\sigma_i+\theta_i\log(z)+\sum_j[\phi^*_{ij}+\tau^*_{ij}\log(z)]\cdot\log(t_j)-\sum_j[\delta^*_{ij}+\psi^*_{ij}\log(z)]\cdot\log(p_j)$$
$$-\left(\psi_i/\rho\right)\log(M/MI)+\psi_i\log(T/TI) \tag{5}$$

Equations (4) and (5) define two share systems or blocks of share equations, one for money expenditure and the other for time expenditure. In addition to the usual symmetry and homogeneity restrictions within share systems, there are cross-system restrictions arising from the $\log(p_i)\log(t_i)$ terms in the expenditure and indirect utility functions. This results in the common terms $[\delta^*_{ij}+\psi^*_{ij}\log(z)]$ in each of (4) and (5). Each activity x_i that has two prices t_i and p_i has two share equations, one explaining the share of time budget the activity consumes and the other explaining the share of money budget it consumes. Each of these share equations is a function of own time price and an own money price, as well as cross-money and time prices and time and money budgets. Those activities for which either $t_i=0$ or $p_i=0$ are represented by only a single share equation; thus there may be asymmetries in the number of equations in each share system.

[2] The deflators are defined as $MI\equiv\alpha_{0m}+\sum_i\alpha_i\log(p_i)+\log(z)\sum_i\gamma_i\log(p_i)+\frac{1}{2}\sum_i\sum_j\gamma_{ij}\log(p_i)\log(p_j)$ $+\sum_i\sum_j\nu_{ij}\log(p_i)\log(t_j)$ and $TI\equiv\alpha_{0t}+\sum_i\sigma_i\log(p_i)+\log(z)\sum_i\theta_i\log(t_i)+\frac{1}{2}\sum_i\sum_j\phi_{ij}\log(t_i)\log(t_j)$ $+\sum_i\sum_j\varphi_{ij}\log(p_i)\log(t_j)$ respectively. We used the linear approximation version of the AIDS model with Stone's price index, so that the terms ν_{ij}, and φ_{ij} are not identifiable separately in the model; instead, we can estimate $\delta_{ij}\equiv\nu_{ij}-\rho\varphi_{ij}$, that is, $\sum_i\sum_j\delta_{ij}\log(p_i)\log(t_j)=\sum_i\sum_j\nu_{ij}\log(p_i)\log(t_j)$ $-\rho\sum_i\sum_j\varphi_{ij}\log(p_i)\log(t_j)$. This embedding of ρ in δ_{ij} accounts for the seeming asymmetry of (4) and (5); in fact each expression for $\log(p_i)\log(t_j)$ in both share systems has a ρ term.

The Data

The data used to illustrate the model are from on-site intercepts of whalewatchers at four sites in California during the winter of 1991-92. The survey instrument was pretested using individuals who had gone whale watching in the previous year. It collected information on trips taken so far that season, expected future trips, travel time, travel costs, whether the trip was their primary destination, etc., were asked. Also collected was information included actual contributions to marine mammal groups, time spent reading, watching, or thinking about wildlife and whales, as well as purchases of whale-related merchandise. Lastly, demographic information including work status, wage rates, and income was asked. The survey was presented in booklet form.

In total, 1,402 visitor surveys were handed out, and 1,003 were returned, for an overall response rate of 71.3%. The response rate was reasonably similar across the four locations, varying from a low of 65.2% for intercepts at Point Loma (San Diego) to a high of 80.3% for intercepts at Point Reyes. On-site refusals were not a problem. For example, at Point Reyes, only 10 people of roughly 600 contacted (about 1.6%) refused to take a survey packet.

Four goods can be used to define the time and money share systems from the whalewatching data set: whalewatching trips; monetary donations to whale- and marine mammal-related organizations; time volunteered for such organizations; and consumption of all other goods. One of the questions of interest for this analysis is whether, and to what extent, whalewatching trips and other consumption activities related to whales are substitutes.

Recreation trips (x_1) involve both money costs, both in travel and onsite, and time costs in the form of travel time required to gain access to the site. There is also a time price onsite, represented by the amount of time in travel and onsite required to complete the trip.[3]

Monetary donations (x_3) have a money price because charitable contributions are tax deductible at both the federal and state level, so the marginal "price" of a dollar

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[3] We take onsite time to be exogeneous, because whalewatching trips in this analysis are all day trips and roughly half the whalewatching trips represented are boat trips of fixed duration. Other variations in time spent onsite, e.g., for shoreline whalewatchers, are small enough to be reasonably treated as negligible.

donation is less than a dollar and varies across individuals according to household income. They do not have a significant time price, so x_3 appears in the money share but not the time share system. For the same reason, the time price of a money donation (t_3) is not an argument of the share systems.

Time donations (x_2) have a time price $t_2 \geq 1$, measured by the ratio of the number of total hours required to deliver an hour of time to the volunteer organization. Total time may be higher because of transactions time costs from driving back and forth, etc. Because we don't have information on how this time price will differ across individuals in our sample, we take the time price $t_2 = 1$ for all. As a consequence, t_2 drops out of the empirical share systems. There may also be a money cost p_2 of time donations, which would represent the money costs of driving to and from the site where volunteering occurs and other transactions costs of donating time. We have no information on this variable from our sample but suspect it is small, thus it is taken to be zero. Thus price p_2 does not appear in the share systems. A further consequence is that time donations appear in the time share system but not the money share system; the time donation share ω_2 is a function of cross prices and budgets but not own time- or money-prices.

The numeraire good is x_4, the residual expenditures of time and money from their respective budgets after accounting for trips and the two donations activities. Time prices and budget are normalized on x_4 so that t_4 is unity and does not appear as an argument in the share systems. This normalization imposes homogeneity on the time share system. It also defines x_4 as residual time expenditures; the money price of x_4 is then $p_4 = (M-p_1x_1-p_3x_3)/(T-t_1x_1-x_2)$, the money expenditure per unit of residual time. Homogeneity is imposed on the money share system by the parameter restrictions $\gamma_{I4} = -(\gamma_{I1} + \gamma_{I3})$.

In addition to the time and money prices, it is expected that the individual's whalewatching success will influence both trips demand and, potentially, the willingness to make donations of time and money. The success variable (z) is the individual's ex ante expectation of whale sightings for the whalewatching trip when they were contacted. Money budget (M) is the household income before taxes, and the time budget is amount of nonworking time in the number of weekend and paid vacation days.

Results

The linear approximate version of the money share (x_1 and x_3) and time share (x_1 and x_2) systems, using Stone's price index for the time and money deflators, were estimated using the nonllinear systems estimator in SHAZAM 7.0. Symmetry restrictions were maintained within each share system and the symmetry conditions implied by (4) and (5) were maintained across share systems. As noted above, homogeneity was also maintained for each share system. Since there was no strong a priori guidance about how quality should enter the share systems, insignificant quality shifters were eliminated from the specifications.

The estimation results are given in Table 1. A likelihood ratio test on the significance of the model strongly rejects the null hypothesis that none of the parameters are significant. Quality effects appear only in the trips time share equation, as an own-(time) price shifter. A likelihood ratio test rejects significant quality effects at the 10% level, though this would not be rejected at the 15% level. The effect of quality is to increase the own time price elasticity of the trips share equation.

The trips equations in both the money and time share systems are of particular interest as they describe whalewatching recreation demand from two different perspectives. Both equations are highly significant and the prices enter with the expected signs and a high level of significance. The trips money share equation is money price-inelastic and slightly inferior at the means of the data; negative income effects are not uncommon in recreation demands. There are two income effects in this model; the second (the time budget effect) is positive, with about unitary elasticity. Cross-money price (the "tax price" of a money donation) and own-time price also enter with significant negative effects. This suggests money donations and whalewatching trips are complements: those who take more trips are likely to donate more heavily. The own time price argument is travel time, a standard argument in trips equations; it has the expected negative effect on trips share.

In the trips time share equation, own time price and time and money budgets are all statistically significant and trips is a normal good with respect to both budgets. Interestingly, travel cost (the money price of travel) does not show up as a significant factor in the trips time share equation. While money costs are important to the trips money share equation, they apparently do not play a major role in the time share decisions.

The money donations equation is of particular interest, as it appears the consumer's surplus from this equation, which represents the net satisfaction obtained by making a donation, may be interpretable as “warm glow.” Donation demand appears to be highly price elastic, and strongly inferior. Because the own (tax) price of a donation is highly (and negatively) correlated with money income, these two effects appear to be offsetting. Further work on specifying this equation is needed before much interpretation can be made.

Conclusions

We have developed and implemented a two-constraint model of recreation and donation choice based on the AIDS expenditure function. Because recreation is a relatively time-intensive activity, time constraints may bind more severely on recreation choice than money constraints and it is important to model the effects of those constraints. The model gives rise to two systems of share equations, one explaining time shares of different activities and the other explaining money shares. In addition to the usual within-share system homogeneity and symmetry restrictions, there are also cross-system symmetry conditions implied by the existence of a coherent underlying preference structure. Each share equation is a function of own- and cross- time and money prices and time and money budgets. The share systems provide a natural way to model substitution by consumers across activities that may be related to their interest in amenities such as whales. When applied to a sample of California whalewatchers who also were asked about their donations of time and money related to whales, we found (a) that the variables predicted to influence choice by theory were statistically significant with signs largely consistent with a priori expectations; (b) that changes in whale-watching success had only a minor influence on the share systems through the trips time share equation; and (c) that the demand for donations may provide interesting insights into the satisfaction derived from giving.

As noted, these results are highly preliminary and much additional work is needed. Among the next steps are to specify the value of time elasticity so that it can vary across the sample with characteristics other than time and money budgets; to introduce those characteristics into the share systems as well; and to further investigate the donations demand and the substitution relationships among the goods in these simple share systems.

Equation/ Variable	Coefficient	Coefficient Estimate	Student's-t	Elasticity at Mean
Money Share System				
Trips Equation				
Constant	α_1	0.171641E-01	6.7963	
Money Price	γ_{11}	0.93492E-03	9.9029	-0.34552
Tax Price	γ_{13}	-0.40046E-03	-2.0049	-0.28034
Travel Time	δ_{11}	-0.66656E-04	-1.8991	-0.04666
Money Budget	β_1	-0.16309E-02	-6.1423	-0.14169
Time Budget	$-\rho \cdot \beta_1$	-1.7E-07		-0.00012
Money Donations Equation				
Constant	α_3	0.35418	4.4955	
Tax Price	γ_{33}	-0.33467E-01	-4.0414	-70.867
Travel Time	δ_{31}	0.24822E-02	1.8611	5.181938
Money Budget	β_3	-0.39970E-01	-4.3985	-82.4429
Time Budget	$-\rho \cdot \beta_3$	-4E-06		-0.00845
Trips Share System				
Trips Equation				
Constant	σ_1	-0.20055E-01	-1.5814	
Travel Time	ϕ_{11}	0.55988E-03	6.7013	-0.42104
Travel Time · Quality	τ_{11}	0.51158E-04	1.4676	0.052901
Time Budget	ω_1	0.24622E-06	1.6137	1.000255
Money Budget	$-\omega_1/\rho$	0.002431		2.513667
Time Donations				
Constant	σ_2	0.96865E-02	0.70355	
Travel Time	ϕ_{21}	0.46644E-04	0.56640	-0.64802
Travel Cost	δ_{21}	-0.73271E-04	-1.9251	-0.55291
Tax Price	δ_{23}	-0.92498E-03	-0.63868	-6.97993
Time Budget	ω_2	-0.10992E-06	-0.67654	0.999171
Money Budget	$-\omega_2/\rho$	-0.00109		-1.12218
Value of Time Elasticity				
	ρ	-0.10129E-03	-25.686	
Log-L	8555.1			
Log-L (coefs=0)	4663.2			
No. of Observations	461			

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