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for Nonmarket Goods

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Measuring Willingness to Pay for Nonmarket Goods

The measurement of willingness to pay for changes in non-traded or nonmarket goods presents a formidable challenge that has received some recent attention (Willig, Hanemann, LaFrance and Hanemann, Neill, Bockstael and McConnell). When the nonmarket good is linked to market goods, it is sometimes possible to obtain valuations of increments (decrements) in the nonmarket good by examining changes in market behavior. One case where this is possible is when the nonmarket good is nonessential and weakly complementary[1] to one or more market goods (Maler; Willig; Bockstael and Kling). While weak complementarity is a plausible condition to impose on preferences in many circumstances, it rules out non-use values of nontraded goods and is likely inappropriate for some unique natural resources or environmental amenities. It would be desirable to find ways to measure use and nonuse values of nonmarket goods from the demands for market goods without having to appeal to weak complementarity.

Some recent work has focused on ways to bound an agent's true marginal willingness to pay for changes in a non-traded good, provided certain information is available, without imposing weak complementarity on the agent's preferences (Neill). One of the purposes of this paper is to show that with the amount of information Neill presumes, it is possible to obtain the agent's *exact* marginal valuation of the non-traded good, which eliminates the need for the bounds he develops. If any good in the estimated demand system or the composite commodity is Hicks-neutral to z, exact marginal valuations can be obtained. Several ways of measuring and bounding this valuation from the coefficients of Marshallian demand systems are discussed. The problem is that Hicks-neutrality imposes a rather specific stucture on the demand system, and it is not possible to determine empirically which good(s) are Hicks-neutral to z.

A second purpose is to pursue further the possibilities for measuring willingness to pay for changes in nontraded goods for preferences that do not (necessarily) exhibit weak complementarity. In particular, some implications of separability restrictions, often assumed in empirical demand analysis, for measuring nonmarket values are explored. It is shown that implicit separability is sufficient to enable the calculation of the willingness to pay for nontraded goods from empirical demand systems. (An alternative condition, homothetic weak separability, is also sufficient.) The results of this paper offer some possibilities for measuring use *and* nonuse values of non-traded goods.

The first section of the paper explains the model to be used, following the development of the recent paper by Neill. It is then shown how the exact value of willingess to pay for marginal changes in nontraded goods can be computed from the information he uses to calculate bounds. The following section shows how separability restrictions like those often used in empirical work provide enough structure to the demand system to permit exact willingness to pay for changes in nonmarket goods. The paper concludes with a discussion of some of the implications for empirical measurement of nonmarket values and the limitations of the approach.

The Model of Choice with a Nontraded Good

The model setup follows Neill's notation. The agent solves the problem

$$\min_{x} px \quad \text{s.t.} \quad U^0 = U(x,z),$$

where x is an n-vector of consumption (traded) goods and p is a conformable price vector, z is a nontraded good, and $U(\cdot)$ is the agent's continuous, differentiable, quasiconcave utility function.[2] In developing the story of measuring willingness to pay for nontraded goods, z will be often be referred to as "quality," though it need not be so narrowly conceived. Substituting optimal (Hicksian) demands $x^c = x^c(p,z,U^0)$ into the objective function gives the (minimum) expenditure function $m(p,z,U^0)$. The solution to the dual problem

$$\max_{x} U(x,z) \quad \text{s.t.} \quad y = px \tag{1}$$

yields Marshallian demands $x=x(p,z,y)$, which are related to the Hicksian demands as $x^c(p,z,U) \equiv x(p,z,m(p,z,U)$. Differentiating this identity with respect to z yields the Slutsky-Hicks equations for changes in the nontraded good:

$$\partial x_i^c/\partial z = \partial x_i/\partial z + (\partial x_i/\partial y)(\partial m/\partial z), \qquad i=1,\ldots,n. \tag{2}$$

As Neill notes, $-\partial m/\partial z = \mu$ is the agent's marginal willingness to pay for a change in z. Making this substitution in (2) and rearranging obtains n different expressions for μ:

$$\mu = (\partial x_i/\partial z - \partial x_i^c/\partial z)/\partial x_i/\partial y. \tag{3}$$

The terms $\partial x_i/\partial z$ and $\partial x_i/\partial y$ are in principle observable since they are, respectively, the quality and income slopes of the Marshallian demand for good i, though the Hicksian quality slope $\partial x_i^c/\partial z$ is not observable.

While μ cannot be determined exactly from the relations (3) in all cases, it can be bounded as a direct consequence of (3) if one knows whether z is a Hicks-complement or Hicks-substitute to good i. One of the main assumptions of the Neill paper is that it is possible to make this kind of determination. If good i is normal, then one knows immediately that the ratio of Marshallian quality to income slopes bounds marginal willingness to pay for z as follows:

$$\frac{\partial x_i/\partial z}{\partial x_i/\partial y} \text{ is an } \begin{Bmatrix} \text{over} \\ \text{exact} \\ \text{under} \end{Bmatrix} \text{ estimate of } \mu \text{ iff z is } \begin{Bmatrix} \text{Hicks-complementary} \\ \text{Hicks-neutral} \\ \text{Hicks-substitute} \end{Bmatrix} \text{ to } x_i \tag{4}$$

The relationships in (4) use the terminology of Neill's very useful Lemma 2, which relates the sign of Hicksian quality slopes to the notion of whether quality and traded goods are Hicks substitutes, complements, or neutral. The relationships in (4) are reversed for inferior goods. It should be mentioned that (3) can be used to develop bounds for μ whether or not $\partial x_i/\partial z$ and $\partial x_i/\partial y$ have the same sign.[3]

Obtaining Exact Measures of Willingness to Pay for marginal quality changes

Based on what is apparently assumed to be known, there is more information about μ that can be gotten out of the problem. To set up the notation, let i index the set of goods that are Hicks-substitutes for z, j index the Hicks-complements, and k index the goods Hicks-neutral to z. This classification is mutually exclusive and exhaustive. In his centerpiece theorem, Neill clearly assumes that it is known that $\partial E_1/\partial y \equiv \sum_i p_i \partial x_i/\partial y$, $\partial E_2/\partial y \equiv \sum_j p_j \partial x_j/\partial y$, $\partial E_1/\partial z \equiv \sum_i p_i \partial x_i/\partial z$, $\partial E_2/\partial z \equiv \sum_j p_j \partial x_j/\partial z$ are positive. The point of the theorem is that bounds for μ can be calculated from these changes in expenditures on groups, and for the bounds to have empirical content the magnitudes of $\partial E_1/\partial y$, $\partial E_2/\partial y$, $\partial E_1/\partial z$, and $\partial E_2/\partial z$ must also be known. But if these are known, there is no need to compute *bounds* for μ, since from this information it can be calculated exactly. This is shown in the following Lemma.

Lemma 1. If $\partial E_1/\partial y$, $\partial E_1/\partial z$, $\partial E_2/\partial y$, and $\partial E_2/\partial z$ are known for a demand system, then exact willingness to pay μ can be obtained for the nontraded good z.

Proof. By definition $-\mu \equiv \partial m(p,z,U)/\partial z$, where

$$\begin{aligned} \partial m/\partial z &= \textstyle\sum_i p_i \partial x_i^c/\partial z + \sum_j p_j \partial x_j^c/\partial z + \sum_k p_k \partial x_k^c/\partial z \\ &= \textstyle\sum_i p_i \partial x_i^c/\partial z + \sum_j p_j \partial x_j^c/\partial z \end{aligned} \tag{5}$$

since by Neill's Lemma 2, $\partial x_k^c/\partial z = 0$ for Hicks-neutral goods. But substituting in the Slutsky-Hicks equations (2), (5) becomes

$$\begin{aligned} \partial m/\partial z &= \textstyle\sum_i p_i[\partial x_i/\partial z + (\partial x_i/\partial y)(\partial m/\partial z)] + \sum_j p_j[\partial x_j/\partial z + (\partial x_j/\partial y)(\partial m/\partial z)] \\ &= \Big(\textstyle\sum_i p_i \partial x_i/\partial z + \sum_j p_j \partial x_j/\partial z\Big) + (\partial m/\partial z)\Big(\sum_i p_i \partial x_i/\partial y + \sum_j p_j \partial x_j/\partial y\Big) \\ &= \Big(\partial E_1/\partial z + \partial E_2/\partial z\Big) + (\partial m/\partial z)\Big(\partial E_1/\partial y + \partial E_2/\partial y\Big). \end{aligned}$$

Solving explicitly for $\partial m/\partial z$, when $\partial E_1/\partial y + \partial E_2/\partial y \neq 1$,

$$\partial m/\partial z = \frac{\left(\partial E_1/\partial z + \partial E_2/\partial z\right)}{\left(\partial E_1/\partial y + \partial E_2/\partial y\right)}, \tag{6}$$

which means the exact willingness to pay for a change in nontraded good z is

$$\mu = -\frac{\left(\partial E_1/\partial z + \partial E_2/\partial z\right)}{\left(\partial E_1/\partial y + \partial E_2/\partial y\right)}. \tag{7}$$

QED.

Equations (6) and (7) show that the distinction between Hicks-substitutes and Hicks-complements to z is not central for purposes of measuring willingness to pay; what is crucial is the distinction between goods Hicks-neutral to z and those not neutral to z (i.e., the substitutes and complements). If one knows the way in which (Marshallian) expenditures on goods that are not neutral to z change with z and with income y, it is possible to determine the marginal willingness to pay for changes in z exactly.

Measuring Willingness to Pay Exactly From Empirical Demand Systems

Since the ultimate purpose of expressions such as (7) is to provide empirical measures of the change in welfare due to quality (or other nontraded good) changes, it is fruitful to think of the problem in terms of incomplete demand systems. In empirical work, the researcher must necessarily specify a structure of how a nontraded good z relates to a set of market goods, and this structure provides the information available with which to calculate changes in welfare. Typically the systems specified and estimated are incomplete, and Hicks' composite commodity theorem or separability is invoked to allow consistent aggregation of all other goods not part of the estimated demand system into a composite commodity.[4] Thinking in these terms distinguishes the circumstances where exact measures of μ can be obtained from those where bounds can be obtained.

To identify these circumstances, suppose that the researcher estimates an incomplete system of $m < n$ demands x(p,z,y) that solve (1), and assumes separability of preferences to consistently aggregate the remaining n - m goods into a composite commodity w with unit price. The corresponding Hicksian demands are $x^c(p,z,u) \equiv x(p,z,m(p,z,u))$ and $w^c(p,z,u) = w(p,z,m(p,z,u)$, where as before m(p,z,u) is the expenditure function obtained from the dual cost-minimization problem and the Slutsky-Hicks equations for changes in z are

$$\partial x_i^c/\partial z = \partial x_i/\partial z + (\partial x_i/\partial y)(\partial m/\partial z), \qquad i=1,\ldots,m \tag{8a}$$

and

$$\partial w^c/\partial z = \partial w/\partial z + (\partial w/\partial y)(\partial m/\partial z), \tag{8b}$$

where $\partial x_i/\partial z$ and $\partial x_i/\partial y$, i=1,...,m are coefficients estimated for the incomplete system and $\partial w/\partial z = -\sum_i p_i \partial x_i/\partial z$ and $\partial w/\partial y = 1-\sum_i p_i \partial x_i/\partial y$ are known from the estimated coefficients and the budget constraint.

Weak separability is a common assumption in empirical demand analysis to permit consistent aggregation of goods omitted from the estimated system. Weak separability is necessary and sufficient for the second stage of two-stage budgeting (see, e.g., Deaton and Muellbauer). An analogous assumption on preferences that implies separability of the *expenditure* function, implicit separability, also allows consistent agregation of a composite commodity and is consistent with both stages of two-stage budgeting. Since a separability assumption is typically made in empirical analyses to facilitate estimation, the consequences of implicit separability for measuring marginal willingness to pay for quality changes are explored.[6]

If the nontraded good z is implicitly separable from goods $x_{m+1},\ldots, x_n$, the expenditure function can be written

$$m(p,p_w,z,u) = m[f(p_1,\ldots,p_m,z,u), g(p_{m+1},\ldots,p_n,u),u], \tag{13}$$

where $g(\cdot)$ is a price index p_w for the composite commodity w; and $\partial m/\partial p_w = w^c$. The Hicksian quantities for the complete system are

$$x_i^c = m_1\frac{\partial f}{\partial p_i} \quad = x_i(p,p_w,z,m(p,p_w,z,u)) \qquad \text{for } i = 1,\ldots,m \tag{14a}$$

and

$$w^c = m_2 \quad = w(p,p_w,z,m(p,p_w,z,u)) \tag{14b}$$

where $m_1 \equiv \partial m/\partial f$ and $m_2 \equiv \partial m/\partial g$. The Marshallian demands $x_i(p,p_w,z,y)$ are estimated and therefore known; the properties of the Marshallian composite commodity $w(p,p_w,z,y)$ can therefore be deduced from the budget constraint.

The change in the Hicksian composite commodity with z is

$$\begin{aligned}\frac{\partial w^c}{\partial z} &= \frac{\partial^2 m}{\partial p_w \partial z} \\ &= \frac{\partial}{\partial z}[m_1\frac{\partial f}{\partial z}] \\ &= m_{12}\frac{\partial f}{\partial z},\end{aligned} \tag{15}$$

where $m_{12} \equiv \partial^2 m/\partial f \partial g$. Noting that the change in expenditure with z is $\partial m/\partial z = m_1(\partial f/\partial z)$, (15) becomes

$$\partial w^c/\partial z = \left(\frac{m_{12}}{m_1}\right)\frac{\partial m}{\partial z}, \tag{16}$$

which depends on the curvature of the macro function $m(\cdot)$. Equation (16) shows that under implicit separability, Hicks-neutrality is not imposed on the composite commodity except when, as a special case, additive separability holds. Additive separability ($m_{12} = 0$) implies that $\partial w^c/\partial z = 0$, as was noted in (12) above. The cross-price effects of interest for the following theorem are

$$\frac{\partial w^c}{\partial p_i} = \frac{\partial^2 m}{\partial p_w \partial p_i} = m_{12} f_i, \qquad \text{for } i = 1,\ldots,m. \tag{17}$$

With these relationships implied by implicit separability (or homothetic weak separability), it is possible to prove the following theorem regarding measurement of willingness to pay for changes in nonmarket goods from empirical demand systems.

Theorem 1. If preferences are implicitly separable in the manner of (13), the willingness to pay for marginal changes in the nontraded good z at the optimum is

$$\mu = x_i \frac{-\sum_{j=1}^{m} p_j \frac{\partial x_j}{\partial z}}{-\sum_{j=1}^{m} p_j \frac{\partial x_j}{\partial p_i} - x_i}, \qquad \text{for } i = 1,\ldots,m \tag{18}$$

Proof. From (14a) and (17), one can write

$$\frac{\partial w^c/\partial p_i}{x_i^c} = \frac{m_{12} f_i}{m_1 f_i} = \frac{m_{12}}{m_1}, \qquad \text{for } i = 1,\ldots,m, \tag{19}$$

and using (19) in (16) gives

$$\frac{\partial w^c}{\partial z} = \frac{\partial w^c/\partial p_i}{x_i^c}\left(\frac{\partial m}{\partial z}\right), \qquad \text{for } i = 1,\ldots,m. \tag{20}$$

From the Slutsky-Hicks relations for changes in z, it is also true that

$$\frac{\partial w^c}{\partial z} = \frac{\partial w}{\partial z} + \frac{\partial w}{\partial y}\frac{\partial m}{\partial z}, \tag{21}$$

so (20) and (21) taken together imply that

$$\frac{\partial w^c/\partial p_i}{x_i^c}\left(\frac{\partial m}{\partial z}\right) = \frac{\partial w}{\partial z} + \frac{\partial w}{\partial y}\frac{\partial m}{\partial z}, \qquad \text{for } i = 1,\ldots,m$$

and solving for $\mu = -\partial m/\partial z$,

$$\mu = \frac{\partial w/\partial z}{\frac{\partial w}{\partial y} - \frac{\partial w^c/\partial p_i}{x_i^c}}, \qquad \text{for } i = 1,\ldots,m. \tag{22}$$

Now from the Slutsky-Hicks relations for price changes,

$$\frac{\partial w^c}{\partial p_i} = \frac{\partial w}{\partial p_i} + \frac{\partial w}{\partial y} x_i^c, \qquad \text{for } i = 1,\ldots,m \tag{23}$$

and using (23) in (22) results in

$$\mu = -x_i^c \frac{\partial w/\partial z}{\partial w/\partial p_i}, \qquad \text{for } i = 1,...,m. \tag{24}$$

Now at the optimum, $x_i^c = x_i$, and both $\partial w/\partial z$ and $\partial w/\partial p_i$ are observable from the coefficients of the estimated demand system and the budget constraint:

$$\frac{\partial w}{\partial z} = -\sum_{j=1}^{m} p_j \frac{\partial x_j}{\partial z}$$

and

$$\frac{\partial w}{\partial p_i} = -\sum_{j=1}^{m} p_j \frac{\partial x_j}{\partial p_i} - x_i, \qquad \text{for } i = 1,...,m$$

and using these in (24) gives (18). QED.

Theorem 1 shows that it is possible to measure willingness to pay for changes in quality or other non-traded goods *exactly* under fairly general conditions-- in fact, under the usual kind of assumption that is typically made in empirical demand analysis to permit consistent aggregation of goods not part of the estimated demand system into a composite commodity. Assuming implicit separability is not equivalent to assuming weak separability (which is perhaps the more common assumption) unless the utility function is homothetic (Blackorby, Primont, and Russell), but implicit separability is consistent with both stages of two-stage budgeting whereas weak separability is consistent only with the second stage (Deaton and Muellbauer). One consequence of the separability assumption is that the willingness to pay for z can be measured with respect to *any* good x_i in the estimated demand system, using all m prices, all m quality slopes, and the m cross-price effects with respect to price of good i. Another consequence of the separability assumption is a restriction on the estimated demand system coefficients for the measure of μ obtained from the system to be unique. Dividing the numerator and denominator of (18) by x_i, it can be seen that for the estimated demand system to yield the same value for μ irrespective of which good i is used in the calculation,

$$\sum_{j=1}^{m} p_j \frac{\partial x_j}{\partial p_i} = K\, x_i \qquad \text{for } i = 1,...,m$$

where K is an arbitrary constant.

It is important to note, though, that while the expression in (18) holds exactly for infinitessimal changes at the optimum, it is an approximation for larger changes in z because the Marshallian demand x_i was substituted in for the Hicksian demand x_i^c in (23). To get the willingness to pay for large changes in the nontraded good z, it is necessary to integrate (24) (or, equivalently, (18)) over the interval of change in z. The willingness to pay for any change in z, from z^0 to z^1, can be written

$$m(z^0) - m(z^1) = \int_{z^1}^{z^0} (\partial m/\partial z)\, dz. \tag{25}$$

When the Marshallian income slope for any good in the estimated demand system is independent of z, it proves possible to measure the willingness to pay for changes in the nontraded good from (25). What is required is to be able to integrate the fraction in (18) involving Marshallian price and quality slopes for all goods in the demand system and the Marshallian demand for the good whose income slope is independent of z.[7] The result is given in the following theorem.

Theorem 2. If preferences are implicitly separable, and for some good x_i in the estimated demand system, the Marshallian income slope $\partial x_i/\partial y$ is independent of z, the willingness to pay for a change in quality from z^0 to z^1 is

$$m(z^0) - m(z^1) = y - [y + \frac{x_i(z^0)}{\partial x_i/\partial y}]\, e^{(\partial x_i/\partial y)[\xi(z^1) - \xi(z^0)]} - \frac{x_i(z^1)}{\partial x_i/\partial y} \tag{26}$$

where $\xi(z) \equiv \int_{-\infty}^{\infty} \psi(z)dz$ and $\psi(z) \equiv [-\sum_{j=1}^{m} p_j \frac{\partial x_j}{\partial z}]/[\sum_{j=1}^{m} p_j \frac{\partial x_j}{\partial p_i} + x_i]$, the negative of the multiplier on x_i^c in equation (18).

Proof. If preferences are implicitly separable, equation (18) holds for all goods in the demand system. Consider a good i for which the income slope does not depend on quality z; i.e., $\frac{\partial^2 x_i}{\partial y \partial z} = 0$. From (18), the change in expenditure with z is

$$\partial m/\partial z = x_i^c(z)\psi(z)$$

since $\partial m/\partial z = -\mu$, where $\psi(z)$ is defined in the premises of the theorem. This can be written equivalently as

$$\partial m/\partial z = \psi(z)[\int(\partial x_i^c/\partial z)dz]$$

$$= \psi(z)[\int(\frac{\partial x_i}{\partial z} + \frac{\partial x_i}{\partial y}\frac{\partial m}{\partial z})dz]$$

from the Slutsky Hicks relations for quality changes. Multiplying this out and using the fact that for good i the income slope does not depend on quality,

$$\partial m/\partial z = \psi(z)[\int\frac{\partial x_i}{\partial z}dz + \frac{\partial x_i}{\partial y}\int\frac{\partial m}{\partial z}dz]$$

$$= \psi(z)[x_i(z) + (\partial x_i/\partial y)\, m(z)]. \tag{27}$$

This is a first order partial differential equation. For purposes of recovering the difference in the expenditure function with changes in z, it can be treated as an ordinary differential equation. Using the integrating factor $\exp[(\partial x_i/\partial y)\int\psi(z)dz] \equiv \exp[(\partial x_i/\partial y)\xi(z)]$, the solution to (27) is

$$m(z) = e^{C + (\partial x_i/\partial y)\xi(z)} - \frac{x_i(z)}{\partial x_i/\partial y},$$

where C is a constant of integration. Note that the constant of integration does not depend on z, since the integration was performed over z. The constant C can be identified by using the initial condition $m(z^0) \equiv y$, since the budget is just exhausted for the initial level of quality z^0. Making use of this initial condition, the constant of integration is

$$e^C = [y + \frac{x_i(z^0)}{\partial x_i/\partial y}]\ e^{-(\partial x_i/\partial y)\psi(z^0)}$$

and the expenditure function is

$$m(z) = [y + \frac{x_i(z^0)}{\partial x_i/\partial y}]\ e^{-(\partial x_i/\partial y)[\psi(z) - \psi(z^0)]} - \frac{x_i(z)}{\partial x_i/\partial y}.$$

Therefore, for any change in z from z^0 to z^1, the willingness to pay for the change is $m(z^0) - m(z^1) = y - m(z^1)$, which is given in (26). QED.

Theorem 2 provides a way to measure discrete changes in quality or other nontraded goods from the observables of an estimated demand system, provided that preferences are implicitly separable and the income slope of at least one of the goods in the demand system is independent of the nontraded good. The approach used in developing the result differs from that used by other authors who have been concerned, directly or in passing, about measuring quality changes from empirical demand systems (Willig; Bockstael and McConnell; LaFrance and Hanemann). These authors have integrated back over price to recover preferences, and all have noted correctly that the constant of integration over price may contain the nontraded good z. Thus in the approach of integrating back over price, part of the information about how preferences depend on z may be lost.

In sharp contrast, the approach of this paper is to exploit the structure implied by implicit separability for the differential equations relating Hicksian and Marshallian demands for quality changes and for price changes. This structure is sufficient to relate the change in expenditure m with z to the observable price and quality slopes of Marshallian demands with z and to Hicksian demands. For the special case where the Marshallian income slope of at least *one* good in the system and z are independent, it is possible to write the Hicksian demand in terms of the expenditure function and the observable Marshallian income slope and demand function for that good. The result is a first order differential equation involving expenditure m, the nontraded good z, and observables from the demand system that depend on z but not on m. Thus, the structure of implicit separability and the independence of income slope for a good from z results in a first order differential equation that governs the way that expenditure m must change with changes in the nontraded good z. This can be integrated *over z*, with an appropriate initial condition, to recover the expenditure function as it depends on z. Unlike the approach of integrating back over price, the expenditure function recovered by this approach contains all the information on z, since the constant of integration is independent of z.

Some limitations and complications should be noted. While the condition that income slope be independent of z for some good is testable, implicit separabililty of preferences may not be. A second complication is that the function $\psi(z)$ may be highly nonlinear in z, in which case an analytical expression for $\xi(z)$ may be elusive. This does not interfere with the derivation of the expression (26) for the willlingness to pay for changes in a nonmarket good, but may may *evaluating* it more difficult and require numerical methods.

Conclusions

This paper has provided several new results on measuring willingness to pay for changes in exogenous nontraded goods (μ) from empirical demand systems. The point of departure is a recent paper by Jon Neill, and it is shown that bounds on μ provided by Neill are not needed since under the information he assumes is available, μ can be calculated exactly. The question of when it is possible to measure μ exactly is addressed from the perspective of empirical demand system estimation. Two situations where μ can be measured exactly from coefficients of the estimated demand system follow directly from the Slutsky-Hicks equations for quality changes and Neill's Lemma 2. They are: (1) If *any* good in the estimated demand system is Hicks-neutral to z, then μ can be calculated directly from that good's quality (z-) slope and income slope (when the good is not neutral to z but is known to be a substitute or complement, then bounds for μ can be computed); and (2) If *all* goods not included in the demand system are Hicks-neutral to z, μ can be computed from all the quality and income slopes and prices in the estimated demand system (here too, bounds can be calculated if all excluded goods are not Hicks-neutral.) While these results may be useful in some settings, the problem is that the conditions cannot be verified; they must be adopted as a maintained hypothesis.

Since separability assumptions are common in empirical demand analysis to permit consistent aggregation of goods excluded from the estimated demand system into a composite commodity, some separability assumptions were analyzed for their implications concerning measurement of μ. The focus was on separability restrictions on the expenditure function rather than on the utility function. Additive separability of z from the goods excluded from the estimated system is sufficient for measurement of μ, but this condition is restrictive. A less restrictive assumption on preferences which also permits exact measurement of μ is implicit separability, which is analogous to weak separability (equivalent if the utility function is homothetic) and is consistent with both the first and second stages of two-stage maximization problems.

While a point estimate for marginal willingness to pay for nontraded goods may be useful in some cases, in many situations the change in the nontraded good is large and discrete. If, in addition to preferences that are implicitly separable, it is the case that for at least one good in the estimated demand system the income slope is independent of the nontraded good, it is possible to measure the total willingness to pay for any change in the nontraded good. This latter condition is easily tested using coefficients of the estimated demand system.

The knowledge that marginal and total willingness to pay for changes in nontraded goods can be measured exactly under implicit separability (and, for the latter, independence of income slope and the nontraded good for some market good) is of some significance in measuring non-use values of natural and environmental resources. If a nontraded good such as environmental quality, threatened species survival, or the like, can be related to a set of market goods, and preferences are implicitly separable, Theorem 1 says that the marginal willingness to pay for changes in the nontraded good can be recovered from the empirical demand system. If the income slopes of the estimated demand system are tested and it is found that one or more are independent of z, Theorem 2 says the willingness to pay for discrete changes in the nontraded good can be recovered. Note that weak complementarity of preferences is *not* assumed; that is, there may not exist a set of market prices that drives the marginal utility of the nontraded good to zero. This means that the what is recovered is the *total* value of the change in the nontraded good, not just the use value.

It is important to stress that even with the results of this paper, judgement by the researcher about the specification of the demand system for estimation is of crucial importance, and it can never be known with certainty which goods are, or are not, separable from the nontraded good. As a number of recent authors (among them, Neill and LaFrance and Hanemann) have noted, it is not possible to obtain welfare measures from incomplete demand systems without imposing some structure. Separability assumptions, while restricting the degree of substitutability among subsets of goods, are made commonly in applied demand analysis to rationalize the construct of a composite commodity. Implicit separability allows the researcher to focus analysis on the interaction of the nontraded good with a subset of all market goods, knowing that a composite commodity can be consistently constructed, that the specification allows some interaction between the composite commodity and the nontraded good (through group expenditure effects), and that the marginal willingness to pay for changes in the nontraded good can be obtained exactly. Further work may uncover less restrictive conditions on preferences for which this aggregation, interaction, and measurement is possible.

Footnotes

1. Weak complementarity of a nonmarket good with a set of market goods means that when consumption of the market goods is zero, changes in the nonmarket good do not affect the level of utility.

2. Neill assumes the utility function is strictly concave, which is stronger than necessary, and is the reason for his conclusion (p.226) that $x_1^1 dp_1/(z_1^1 - z_1^0)$ is a lower bound on willingness to pay for a traded good z_1 (μ_{z_1}).

3. In interpreting the Slutsky equations for change in z (his equation (4), p. 228), Neill seems to limit their use as a bound on μ to occasions where the Marshallian quality and income slopes are of the same sign, which is unnecessarily restrictive. He also notes that an exact value for μ can be obtained when one or more goods are Hicks-neutral to z in his footnote 8, but the discussion in the text (p.231), while correct, may be slightly misleading. The text discussion implies that one must know how expenditures on all Hicks-neutral goods change with z and y, when all that is required is the change in expenditure for any one Hicks-neutral good. Furthermore, the set of Hicks-neutral goods have a very restrictive structure of Marshallian demands: $(\partial x_i/\partial z)/(\partial x_i/\partial y) = (\partial x_j/\partial z)(\partial x_j/\partial y)$ for all goods i and j that are Hicks-neutral to z.

4. LaFrance and Hanemann have recently shown that weak integrability is sufficient to permit a composite commodity to be constructed consistently.

5. This condition, that the composite good have some income elasticity, is quite plausible; in fact, its converse (that income elasticity be zero) is extremely restrictive.

6. Implicit separability of preferences is explored because its consequences for the expenditure function are clear and can be related directly to willingness to pay. With weak separability, the implications for the form of direct utility are clear, but it is difficult to determine the restrictions weak separability implies for the expenditure function unless preferences are also homothetic (see, for example, Blackorby, Primont, and Russell, pp. 86-100).

7. In practice, this expression can be a very complicated functions of z, so analytical solutions may be difficult to obtain, but it is possible to evalutate this integral numerically using methods like those in Vartia.

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