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Working Paper

Non-cooperative decision: Making and measures of household surplus

CSERGE Working Paper EDM, No. 03-12

Provided in Cooperation with:

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Suggested Citation: Bateman, Ian J.; Munro, Alistair (2003) : Non-cooperative decision: Making and measures of household surplus, CSERGE Working Paper EDM, No. 03-12, University of East Anglia, The Centre for Social and Economic Research on the Global Environment (CSERGE), Norwich

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**NON-COOPERATIVE DECISION-
MAKING AND MEASURES
OF HOUSEHOLD SURPLUS**

by

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CSERGE Working Paper EDM 03-12

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Acknowledgements

The support of the Economic and Social Research Council (ESRC) is gratefully acknowledged. This work was part of the interdisciplinary research programme of the ESRC Centre for Social and Economic Research on the Global Environment (CSERGE).

ISSN 0967-8875

Abstract

Given the evidence against the unitary model of the household, there is a need to understand the predictions of alternative household models within the context of valuation. This paper derives the relationship between household and individual willingness to pay (WTP) for the non-cooperative model of the household. We stress the dependence of WTP on a) the conjectures held by respondents about the behaviour of other members of the household and b) on whether all the members of the household make contributions to household public goods. The results suggest that the relationship between individual WTP and household WTP may be a complex one and that identifying gender-specific environmental preferences may not be possible within standard stated preference exercises.

Keywords: contingent valuation; consumer surplus; household behaviour; gender, Nash, stated preference.

1. Introduction

The derivation of willingness to pay (WTP), willingness to accept compensation (WTA) and other measures of consumer surplus have been thoroughly explored at the level of the individual, but far less attention has been paid to their counterparts for the multi-person household, despite the fact that most stated preference exercises are conducted on samples where single person households are in the minority. Quiggin (1996) has obtained some useful results in the context of households where the distribution of resources is Pareto-efficient and where member individuals show altruism for one another. Strand and Aabø (2002) extend this research for the Nash bargaining case. However, the Pareto-efficient model is just one amongst several competing models of household behaviour, none of which can claim unequivocal support from behavioural data (Doss, 1996). In this paper we complement Quiggin's work by deriving some results for the non-cooperative model of the household, which differs from the cooperative model in a number of important respects. Our claim is not that the non-cooperative model is universally superior to its competitors, such as the unitary and co-operative models. Rather, our starting point is that different households may operate along different lines and consequently practitioners of stated preference methods such as contingent valuation need to be aware of the implications of different models of the household when designing survey instruments.

One of the key messages of this paper is the importance of *conjectures*, in the sense that the surplus of an individual member of a multi-person household is dependent on the actions of other members of the household. Consequently, when asked for WTP or WTA, the answer he or she provides will typically depend both on the beliefs held about the behaviour of the remaining members of the household *and* on beliefs held about the charge or contribution that would be levied on those other individuals. We highlight these issues in what follows

The plan for the paper is as follows: in the following section we provide a brief discussion of models of household decision-making. We then introduce a simple two-agent model of the non-cooperative household (section 2), define different notions of surplus (section 3) and consider implications for household and individual WTP (Section 4). Section 5 concludes by summarising our main findings and providing some thoughts on the implications of our results for the design of contingent valuation and its sibling valuation methods.

2. Models of Intra-Household Resource Allocation

There are three main models of the household employed in economics: the *unitary*, the *Pareto-efficient* or *cooperative* model and the *non-cooperative* model. In the unitary approach the household is treated as if it is a single agent with a single set of preferences - either because all members actually have the same preferences (and there are no public goods local to the household) or because the structure of altruism and incentives within the household align individual preferences. For instance, in Becker's (1974) 'rotten kid theorem' models, assumptions about individual preferences and behaviour imply that all members of the household act to maximise its income.¹ One of the central predictions of the unitary model is that of income pooling: the allocation of expenditure should not be affected by the source of household income. However, Browning and Chiappori (1998) use family expenditure data to show the systematic influence of the source of income on expenditure shares for male and female clothing. Meanwhile Phipps and Brown (1998) obtain a similar result for eight out of twelve categories of consumer goods. Within the contingent valuation literature, evidence on the limitations of the unitary model is provided by Lampietti (1999) who finds a significant difference in the willingness to pay of husbands and wives for household public goods in Ethiopia. Other predictions of the unitary model and studies providing strong evidence against it, from both developing and developed nations, are summarised by Doss (1996) and also in the survey of Alderman *et al.*, (1995), which consequently proposes the abandonment of the unitary approach as the default option for modelling households.

The principal alternatives to the unitary approach are game theoretic. In the co-operative approach, pioneered by Manser and Brown (1980) and by McElroy and Horney (1981), adult individuals in the household are assumed to bargain over the allocation of resources. A variety of different alternatives have been put forward for the disagreement point or fall-back position, including divorce and non-cooperation, but a common feature of the co-operative approach is the assumption of the Nash bargaining solution and hence of Pareto efficiency in the allocation of resources. Taking this as its starting point, in the approach of Chiappori and his collaborators the details of the process of intra-household bargaining are left unmodelled; all that is assumed is that the outcome is Pareto efficient (see Browning *et al.*, (1994), or Browning and Chiappori (1998) for instance). Efficiency implies that the marginal rates of substitution of the family members should be equal; under additional but mild conditions, (Browning and Chiappori, 1998), it also implies that the household Slutsky matrix is the sum of a symmetric negative semi-definite matrix and a matrix of rank at most one. Tests of the

¹ As pointed out by Bergstrom (1989), the rotten kid theorem may fail to hold when the number of commodities is two or more.

cooperative model yield conflicting results. Browning *et al.* (1994), and Browning and Chiappori (1998) reject the unitary model in favour of the cooperative alternative. Against this, Jones (1983) rejects efficiency in household allocations in the Cameroon, Udry (1996) finds differing rates of marginal productivity and marginal rates of substitution in data in farm level data in Burkina Faso and Udry and Duflo (2001) similarly reject the Pareto efficient model for farm households in the Côte d'Ivoire.²

In contrast to the co-operative approach, in non-cooperative models, (Chen *et al.*, (2001) and Bolin *et al.*, (2002) for instance), efficiency is not normally the outcome: individuals within the household choose contributions to household goods and their own private consumption taking the actions of the other members of the household as given. As a result the equilibrium concept is that of (Cournot) Nash equilibrium, which may leave scope for Pareto improvements. There are arguments for and against such a model. One might view the household as a natural venue for repeated interaction and hence anticipate some iteration towards efficient outcomes. For instance, the conditions of the Folk Theorem are more likely to be satisfied in long-run relationships with repeated interaction. Against this, the conditions of the Folk theorem need not be satisfied if there is a significant probability of dissolution of the relationship (i.e. divorce) or when there is private information about the costs and benefits of actions or about whether spending agreements have been adhered to (Kandori, 2002). Thus there are theoretical reasons why the non-cooperative approach might be appropriate for some households. Empirically, the evidence which rejects the unitary model is compatible with the predictions of the non-cooperative model.³ Moreover, as we have seen, cooperative theories are not entirely satisfactory as empirical vehicles for describing household behaviour. So, as with the theoretical arguments there are empirical reasons for giving consideration to the non-cooperative approach. We do this in the next section using a simple model of a two agent household.

² In none of these cases, though is the alternative of the unitary model supported. For instance, Udry (1996) states that 'a large number of empirical studies have cast doubt on the unitary household model. By now it is clear that the whenever matters substantially related to intra-household distribution are under investigation, the unitary household model must be discarded' p. 1044.

³ See also Bolin *et al.*, (2002), for a discussion of health-related evidence for the non-cooperative model.

3. A Non-Cooperative Model of the Household

Consider two individuals, $i=1,2$ with preferences summarised by the utility functions: $u^i = u^i(m^i, t^i, y^i, y^{-i}, z) = u^i(m^i - t^i - y^i, Y, z)$, where z is a public good, $Y = y^1 + y^2$ is total contributions to a household public good⁴ (called simply the household good, hereafter) and $m^i - t^i - y^i$ is the i th individuals' expenditure on a composite private good, which in turn is equal to their income, m^i , less their contribution to the household good, y^i , and any charge or tax, t^i , (or other form of contribution) made for the public good. The term y^{-i} represents the contribution of the other agent to the household good. We shall make the following assumption about preferences:

A1 U^i is twice differentiable and increasing in all its arguments and concave. Moreover, the household good is normal – i.e. $dy^i/dm^i > 0$ whenever $y^i > 0$.

In the non-cooperative model, each individual chooses y^i to maximise his or her own utility function. Equilibrium is then the Nash equilibrium of the simultaneous play game. That is:

$$y^{i*} = \arg \max_{y^i} (U^i(m^i - t^i - y^i, y^i + y^{-i*}, z)) \quad i=1,2. \quad (1)$$

where * indicates the equilibrium choice of y and $-i$ is used to indicate the choice of the other player. Using the assumption of differentiability, therefore at an interior Nash equilibrium:

$$-U_1^i(m^i - t^i - y^i, y^i + y^{-i}, z) + U_2^i(m^i - t^i - y^i, y^i + y^{-i}, z) = 0 \quad i=1,2. \quad (2)$$

where subscripts represent partial derivatives.

For simplicity in what follows we shall make the following assumption:

A2 The Nash equilibrium is unique and stable.⁵

The properties of this kind of model are well-known from the public goods literature. In particular, a theorem by Warr, [31], extended by Bergstrom *et al.*, (1986), shows that the value of Y is unchanged by a redistribution of income, provided that the set of contributors remains unchanged. The intuition behind the

theorem can be seen from the first order conditions for a Nash equilibrium. A transfer of Δm from individual i to $-i$, accompanied by a simultaneous reduction in y^i of Δm and a rise in y^{-i} of Δm leaves the conditions unchanged. Only if one or more of the agents is at a corner solution will a redistribution lead to a change in the value of the household public good. We will use this notion extensively in what follows.

⁴ Y may be interpreted in different ways: it could for instance be contributions to housing or heating or pooled household expenses or it could be expenditure on dependents.

⁵ The conditions under which the Nash equilibrium is unique are not particularly restrictive, but neither do they follow automatically from assumptions of well-behaved preferences, as is shown by Fraser (1992) and Cornes *et al.*, (1999).

4. Measures of Surplus

We concentrate initially on WTP measures for a change in the public good from z to z' , with $z' > z$. Write household welfare as $W(m^1, m^2, y^1, y^2, t^1, t^2, z)$. Household WTP is then defined as $WTP = t^1 + t^2$ where the t 's are non-negative real numbers defined implicitly by:

$$W(m^1, m^2, y^1, y^2, t^1, t^2, z') = W(m^1, m^2, y^1, y^2, 0, 0, z) \quad (3)$$

It is usual to write household welfare as an increasing function of the welfare of individual members of the household, viz: $W = W(U^1, U^2)$, in which case the t 's are defined by,

$$W(U^1(m^1, t^1, y^1, y^2, z'), U^2(m^2, t^2, y^2, y^1, z')) = W(U^1(m^1, 0, y^1, y^2, z), U^2(m^2, 0, y^2, y^1, z))$$

We can define *Nash* household WTP as the set of values of t^1 and t^2 which satisfy this equation and where y^1 and y^2 also satisfy the conditions for Nash equilibrium (equation one). Write this as,

$$W(U^1(m^1, m^2, t^1, t^2, z'), U^2(m^1, m^2, t^1, t^2, z')) = W(U^1(m^1, m^2, 0, 0, z), U^2(m^1, m^2, 0, 0, z)) \quad (4)$$

In this formulation Nash household WTP is not uniquely defined – rather there may be a locus of $\mathbf{t} = (t^1, t^2)$ values which solve equation (4). For instance we could select the combination where the t 's are *equal*, or we could choose the combination which *maximises* total extracted surplus. Alternatively we could choose the combination where each individual is indifferent between the Nash equilibrium outcome with the charges and the higher level of the public good and the Nash equilibrium outcome with no charges and the lower level of public good. We shall call this the *joint* household WTP (JWTP), but as the other examples illustrate and figure 1 shows it is most definitely not the only possible definition of household WTP – Nash or otherwise - in these circumstances.

We now turn to the relationship between measures of individual WTP and measures for the household. There are an uncountable number of different conjectures which one individual may hold about the behaviour of the other member of the household, when the individual formulates a WTP value. We consider four different kinds of conjecture, each of which has some claims to 'reasonableness'. In doing so, we assume Nash equilibrium behaviour for the status quo, where the level of the public good is z , but otherwise we do not

automatically assume Nash conjectures.⁶ One reason for not doing so is to provide a general model of surplus measurement within the non-cooperative model. Another reason is the considerable experimental evidence showing that individuals very often do not play Nash equilibrium strategies, especially in the first play of a new or modified game (see for instance Stahl and Wilson (1994) and Stahl (2000), or the surveys on experimental games in Kagel and Roth (1995)). However, the primary reason for not assuming Nash conjectures is the nature of the process by which WTP values are typically elicited within contingent valuation. Of course it is reasonable to suppose that over time, through repeated play, individuals may come to learn the Nash equilibrium strategy. But in many survey exercises, individual subjects may not have the time or the incentive to compute the likely responses of household members to changes in their own behaviour and from that estimate the configuration of the new Nash equilibrium. Consequently, it is worth considering out of equilibrium conjectures and how they influence measures of surplus.

We give definitions of the four scenarios first, followed by motivating circumstances in which the relevant conjectures might reasonably be expected to obtain. Table 1 summarises the four cases. We now use the superscript * to denote the values of the variables at the Nash equilibrium when the public good level is z and $\mathbf{t}=0$.

Disequilibrium individual WTP (t^{i1}) is defined as the value of t^i which solves the equation:

$$U^i(m^i - y^{i*}, y^{i*} + y^{-i*}, z) = U^i(m^i - t^i - y^{i1}, y^{i1} + y^{-i*}, z') \quad i = 1, 2. \quad (5)$$

and

$$y^{i1} = \arg \max_{y^i} (U^i(m^i - t^i - y^i, y^i + y^{-i*}, z')) \quad i = 1, 2.$$

In other words, individual WTP is calculated on the assumption that the other individual maintains their original contribution to the household good and faces no charge for the improvement to the public good.

Equilibrium individual WTP (t^{i2}) is defined as the value of t^i which solves the equation:

$$U^i(m^i - y^{i*}, y^{i*} + y^{-i*}, z) = U^i(m^i - t^i - y^{i2}, y^{i2} + y^{-i2}, z') \quad i = 1, 2. \quad (6)$$

⁶ By Nash conjectures we mean the assumption that the other player plays their Nash equilibrium strategy.

Meanwhile,

$$y^{i2} = \arg \max_{y^i} (U^i(m^i - t^i - y^i, y^i + y^{-i2}, z^i))$$

and

$$y^{-i2} = \arg \max_{y^{-i}} (U^{-i}(m^{-i} - y^{-i}, y^{i2} + y^{-i}, z^i)).$$

In other words, individual WTP is calculated on the assumption that the other individual faces no charge, but contributions to the household good adjust to a new Nash equilibrium.

Uniform charge, equilibrium individual WTP (t^{i3}) is defined as the value of t^i which solves the equation:

$$U^i(m^i - y^{i*}, y^{i*} + y^{-i*}, z) = U^i(m^i - t^i - y^{i3}, y^{i3} + y^{-i3}, z^i) \quad i = 1, 2. \quad (7)$$

Meanwhile,

$$y^{i3} = \arg \max_{y^i} (U^i(m^i - t^i - y^i, y^i + y^{-i3}, z^i))$$

and

$$y^{-i3} = \arg \max_{y^{-i}} (U^{-i}(m^{-i} - y^{-i} - t^i, y^{i3} + y^{-i}, z^i)).$$

In other words, individual WTP is calculated on the assumption that the other individual faces the same charge and contributions to the public good adjust to a new Nash equilibrium.

Finally, as discussed above, *joint* WTP (JWTP) is defined as $t^{14} + t^{24}$ where each t^i solves the equation:

$$U^i(m^i - y^{i*}, y^{i*} + y^{-i*}, z) = U^i(m^i - t^i - y^{i4}, y^{i4} + y^{-i4}, z^i) \quad i = 1, 2. \quad (8)$$

and

$$y^{i4} = \arg \max_{y^i} (U^i(m^i - t^i - y^i, y^i + y^{-i4}, z^i)) \quad i = 1, 2.$$

Table 1 summarises the four cases.

Table 1: Alternative conjectures

	Conjecture for t^i	Conjecture for y^{-i}
1 <i>Disequilibrium</i>	0	Original value
2 <i>Equilibrium.</i>	0	Nash
3 <i>Uniform charge</i>	t^i	Nash
4 <i>Joint</i>	Set so that U^{-i} equals its original value	Nash

One way of viewing these cases is that each might arise within a typical CV framework. For instance, disequilibrium individual WTP might be evoked in a survey which involves asking each individual, separately, for their WTP for the good, with no prompts about the behaviour of other members of the household. Each individual might then provide an answer on the assumption that the other person's contribution to the household good remains unchanged and that the other person does not face a charge for the public good.

The second value for WTP might be evoked in a survey which involves the same, separate approach, but where the individual thinks through the revised household expenditure game, and gives an answer on the assumption that is consistent with the Nash equilibrium of the game where he or she makes a contribution of t^i and the level of the public good has changed from z to z' . As in the previous case, he or she assumes that the other player does not face a charge for the public good. The third case is similar to the second, except that now the individual conjectures that the other individual in the household faces the same charge. It might be evoked in a dichotomous choice framework in which the individual was told that all individuals would face the same charge, or when the respondents makes such an assumption, because uniformity is a typical feature of tax systems. In the fourth motivating scenario, each individual might be asked for his or her individual WTP and give an answer which assumes that a) the other person also faces the same question, answers it truthfully and b) the levels of contribution to the household good are at their Nash equilibrium values in the revised game where players are making their contributions t^i and face the increased value of the public good, z' .

5. Household and Individual WTP

Given this variety of ‘reasonable’ conjectures, we now consider the relationships between conjecture and WTP and between individual and household measures of WTP.

In some situations the following property may be true:

NC There exists $\mathbf{t} \geq \mathbf{0}$, such that at the resulting Nash equilibrium, $y^1 = 0$ while $y^2 > 0$ and $\mathbf{t}' \geq \mathbf{0}$, such that at the resulting Nash equilibrium $y^2 = 0$ while $y^1 > 0$.

NC states that for both agents there are points along the household WTP locus for which he or she ceases to contribute to the household good. Whether this property holds depends on preferences, incomes, z and z' . If the t 's could take on negative values, then NC would follow from A1 and A2, but if we constrain the willingness to pay value to be positive for each individual, then NC need not hold. For instance, for a small improvement in the public good all non-negative individual payments which keep household welfare unchanged may not be large enough to stop either individual contributing to the public good.

The first proposition sets out some general features of the Nash household WTP locus.

Proposition 1. *Suppose A1 and A2. (i) Nash household WTP is constant for all values of (t^1, t^2) such that $(y^1, y^2) > 0$; (ii) and if NC then Nash household WTP is maximised by setting \mathbf{t} such that one individual does not contribute to the household good.*

Proof (see appendix).

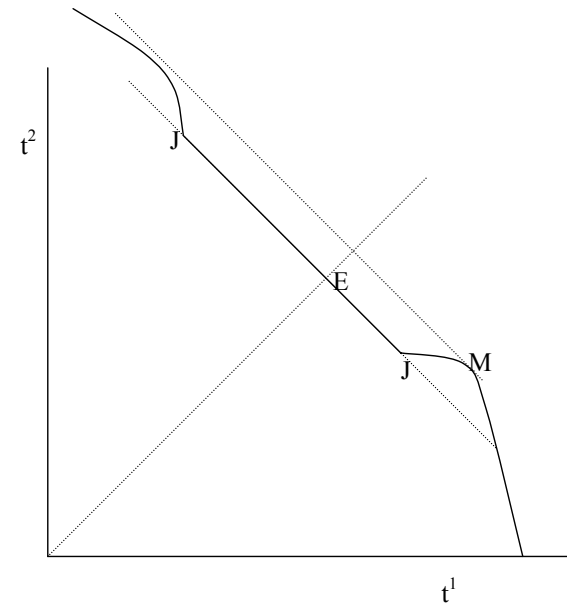
The first part of this proposition follows from Warr’s (1983) theorem, discussed above. The second part is related to Theorem 4 in Itaya *et al.* (1997), where the authors show that greater inequality may raise the level of voluntary contributions to a public good. The corresponding result here is,

Corollary. *If A1, A2 and NC then Joint household WTP < maximum Nash household WTP.*

Proposition 1 and its corollary establish the shape of the Nash household WTP locus, as shown in figure 1, which is drawn under the assumption that NC holds true. The straight section of the locus, JJ, at 45 degrees to the axes, represent the values of t^1 and t^2 for which both individuals make positive contributions to the

household good. Since utility is constant for both individuals along this section of the locus, then all points along it represents joint household WTP combinations. The point where contributions are equal, E, is shown as lying within this region, though it need not. Outside the segment JJ, the locus is curved and one agent ceases to contribute to the household good. Following the corollary, M represents the maximum willingness to pay point, where only one person contributes to the public good.

Figure 1: The Household WTP locus.



The next two propositions establish some features of WTP when individuals make Nash equilibrium conjectures about the behaviour of the other family member.

Proposition 2. Suppose A1 and A2. (i) Provided both individuals contribute to the household good, then for each person, equilibrium individual WTP equals JWTP. (ii) If only one individual contributes, then the sum of equilibrium individual WTP values is higher than JWTP.

Proof (see appendix).

Proposition 3. Suppose A1 and A2 then (i) if both individuals contribute to the household good, the sum of the uniform charge equilibrium WTP values equals the JWTP; (ii) if only one person contributes to the household good, then the sum of the uniform charge equilibrium WTP values exceeds the JWTP provided that the contributor pays a higher charge for the public good in the joint case. When the non-contributor to the household good pays the higher charge, then JWTP exceeds the sum of the uniform charge equilibrium WTP values.

Proof (see appendix).

Propositions 1-3 show that when Nash equilibrium behaviour holds there is a relatively straightforward relationship between individual WTP and JWTP: if both agents contribute to the household good then the individual WTP of each of them is equal to JWTP.⁷ Outside of Nash equilibrium, however, the situation is more complicated, with the general relationship between the sum of individual WTP values and JWTP depending on the degree of complementarity or substitutability between the public good and the other two goods. One benchmark case is that of separable preferences – specifically, when the marginal rate of substitution between good 1 and good 2 is independent of the value of the public good:

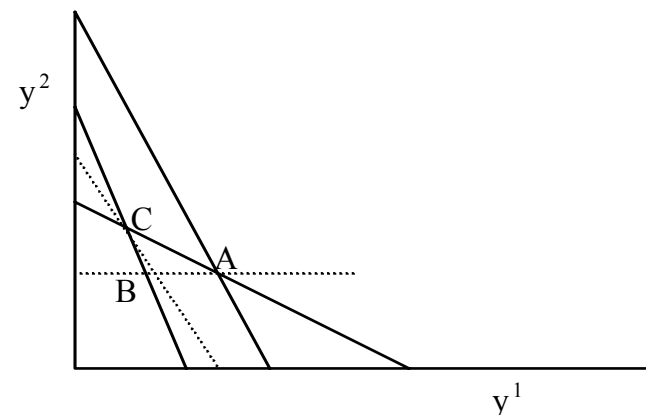
S Separability: $\partial(u_i^1/u_i^2)/\partial z = 0 \quad i=1,2$.

Proposition 4. Suppose A1 and A2 and S, then (i), if $y^{i*} > 0$ for both agents, then individual disequilibrium WTP is less than individual equilibrium WTP for both agents, but the sum of individual disequilibrium WTP is greater than the JWTP; (ii) if $y^{i*} = 0$ for one agent then disequilibrium WTP equals equilibrium WTP for that agent, while the sum of individual disequilibrium WTP is greater than the JWTP. *Proof.* See appendix.

The idea behind Proposition 4 can be seen from Figure 2, which shows reaction functions (a la Cournot) for each player in (y^1, y^2) space for the benchmark case of separability between the z and the other two goods. For simplicity, the curves are shown as straight lines. Consequently, changes in z do not affect the position of the reaction functions. Stability implies that the steeper curve is that of player one,

while the concavity of the utility functions implies that lines representing constant values for Y are shallower than the reaction function for player 1 and steeper than the reaction function for player two.

Figure 2: Disequilibrium and equilibrium individual willingness to pay



In this figure, A represents the initial Nash equilibrium. If a charge of t^{11} is extracted from player 1, then his or her reaction curve shifts inwards. Point C is the Nash equilibrium for the modified game. Point B then represents the contributions to the household good for the case of player one's disequilibrium individual willingness to pay, given that player one conjectures that player two continues to make the original contribution to the household good. It can be seen that B lies beneath the broken line through C which represents combinations of y^1 and y^2 that produce the same level of the household good as at C. Hence at B, the level of the household good is lower compared to C, while player one's contribution is higher. It follows that player one is worse off at B compared to C and therefore that equilibrium individual WTP for player one is higher than disequilibrium individual WTP.

The assumption of separability in Proposition 4 establishes a benchmark for the relationship between individual disequilibrium WTP and its equilibrium counterpart. Separability is a reasonable assumption in some cases: preferences between different combinations of private goods and central heating or children's

⁷ We concentrate on the two person household, but it is worth noting that the same result holds true for the n -agent household, provided all agents contribute to the household good.

education are unlikely to be affected by the extent or quality of a distant wetland. However, there are combinations of household and public good where the assumption is less reasonable – double-glazing and airport noise, for example. A positive sign for $\partial(u'_1/u'_2)/\partial z$ means that as the public good rises the individual's willingness to pay for increments in the household good decreases. In this sense the household good and the public good are substitutes. A negative sign is indicative of complementarity. Proposition 4 still holds with substitutes. Indeed, holding all else equal, as $(u_{13}-u_{23})$ rises, then the gap between disequilibrium and equilibrium values for WTP increases. Basically, if z and y are substitutes, then a rise in z leads to a switch away from y in equilibrium. So, the greater the degree of substitutability, the greater the gap between disequilibrium and equilibrium values of y and thus between the two values for WTP. Conversely, if z and y are strong enough complements, then the relationship between individual disequilibrium WTP and its equilibrium counterpart may be reversed, in the sense that the disequilibrium individual WTP may be greater than equilibrium individual WTP.

6. Discussion

This paper has derived the relationship between different measures of WTP for one particular model of the household. As we emphasised in the introduction, there are several competing models of household behaviour, of which the non-cooperative model is only one. Table 2 summarises the results, assuming separability between the public good and the other two goods. Joint WTP (JWTP) is taken as the benchmark, while Σ WTP indicates the sum of individual WTP values. For reference, the final two columns includes a summary of some of Quiggin's results for the co-operative model of the household. Obviously care must be taken in drawing comparisons, since the non-cooperative and co-operative models are different. Quiggin compares the sum of individual WTP with household WTP (labelled HWTP in the table). He obtains different results depending on whether the individuals within the household show non-paternalistic altruism, paternalistic altruism towards consumption of the private good, but not towards household or public goods or paternalistic altruism towards the household and public goods, but not towards consumption of the private good. It is only in the second of these cases that the sum of individual WTP diverges from the household WTP figure. The table therefore reveals a fairly complex pattern for the relationship between surplus figures for individual members of the household and for the household as a whole. In general the Σ WTP exceeds household WTP (though there is an exception to that rule), and may be up to twice the JWTP. Consequently, when placed alongside the results of Quiggin (1996), one of the lessons for CV to be taken from this paper is that, without knowing some details about household decision-making processes, it is not generally possible to make inferences about household WTP on the basis of answers given by individuals.⁸

Comfort might be taken from the fact that under certain conditions, the measures elicited from individuals will give an accurate figure for Nash household or joint WTP. If the household is unitary then the individual's WTP will also be the household WTP; if the household is non-cooperative, then the individual's WTP will also be the (Nash) household WTP, provided all income earners contribute to the household good and individuals have Nash conjectures; if the household is Paretian, though, individual WTP will only equal household WTP if others in the household place no value on the public good. It would be useful to know if these conditions hold, but there is so far little research on the subject.

⁸An example of how this can make a difference to the results is provided in Roy Brouwer *et al.* (2001). After answering a standard WTP question, members of multi-person households were asked if they had answered as individuals or as part of a household. Just over half the respondents replied that they had answered the question as members of a household. Median WTP was NZ\$589 for the 'household' responders, NZ\$271 for 'individual responders'.

In this paper we have concentrated on the implications for household WTP of individual WTP, but the theory of the household also holds implications for making inferences about individual WTP on the basis of household WTP figures. For instance, gender is routinely included as an explanatory variable in estimated bid curves (see Teal and Loomis (2000) for a recent instance). The lesson from each of the models of the household (unitary, cooperative and non-cooperative) is that gender-based differences in WTP may not be identifiable using standard contingent valuation methods in which gender is added as a potential explanatory variable in the bid equation. To see this, consider a population composed of households with two adults, one male and one female and where matching is uncorrelated with preference strengths for public goods. Within this population, the unitary model predicts no relationship between the gender of a respondent and reported WTP, even if, as individuals, one gender has a systematically higher WTP than the other. The non-cooperative model can also lead to no relationship, if both partners contribute to the household good and respondents hold Nash conjectures. Finally the Paretian model is also compatible with no significant gender effects in estimated bid equations.⁹ Estimating gender effects reliably therefore requires a more careful treatment of the impact of household structure on willingness to pay.

It is worth reiterating that we do not claim that the non-cooperative model applies to all households. Rather, given the evidence on household decision-making, different types of model will be more or less appropriate to different households in different cultures. This fact suggests that it might be worthwhile including into stated preference surveys questions which attempt to aid the process of identifying the model of behaviour which is most appropriate for the household being questioned. Further, there is a need for experiment, in order to discover the relationship between survey design and conjectures and it might also be useful to include reminders and prompts in questionnaires so as to encourage specific conjectures about the behaviour of non-respondents.

Table 2: Comparing Measures of WTP

	Non-cooperative model			Paretian model (Quiggin, [23])		
	$y^{ii} > 0$, both individuals	$y^{ii} = 0$ for one individual, contributor has higher WTP	$y^{ii} = 0$ for one individual; contributor has lower WTP	Non-paternalistic altruism	No altruism in the private good	Altruism in the private good
Disequilibrium	$2JWTP > \Sigma WTP > JWTP$	$\Sigma WTP > JWTP$	$\Sigma WTP > JWTP$	-	-	-
Equilibrium	$\Sigma WTP = 2JWTP$	$\Sigma WTP > JWTP$	$\Sigma WTP > JWTP$	-	-	-
Uniform charge	$\Sigma WTP = JWTP$	$\Sigma WTP > JWTP$	$\Sigma WTP < JWTP$	-	-	-
Individual	-	-	-	$\Sigma WTP = HWTP$	$\Sigma WTP = HWTP$	$\Sigma WTP > HWTP$

⁹ One implication of this observation is that the significance of the gender variable under such conditions provides a test of the unitary model.

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Appendix

PROPOSITION 1. *Suppose A1 and A2. (i) household WTP is constant for all values of (t^1, t^2) such that $(y^1, y^2) > 0$; (ii) and if NC then household WTP is maximised by setting t such that one individual does not contribute to the household good.*

Proof. Part (i) follows from Warr's theorem. To see part (ii) note first that for infinitesimal changes in t^1 and t^2 , we have:

$$dW = W_1(-u_1^1[1 + \frac{dy^1}{dt^1}]dt^1 + u_2^1[\frac{dy^1}{dt^1}dt^1 + \frac{dy^2}{dt^2}dt^2]) + W_2(-u_1^2[1 + \frac{dy^2}{dt^2}]dt^2 + u_2^2[\frac{dy^1}{dt^1}dt^1 + \frac{dy^2}{dt^2}dt^2])$$

Case i. Suppose that the t^i are set such that y^1 is just equal to zero i.e. the marginal condition $u_1^1 = u_2^1$ holds. Now consider $dt^1 = -dt^2 > 0$. In this case, the equation for dW reduces to:

$$dW = -dt^1(W_1u_1^1[1 + \frac{dy^2}{dt^2}] - W_2u_1^2).$$

Case ii. Consider now setting the t^i such that y^2 is just equal to zero i.e. $u_1^2 = u_2^2$ holds. Consider $dt^2 = -dt^1 > 0$, in which case we have,

$$dW = -dt^2(W_2u_1^2[1 + \frac{dy^1}{dt^1}] - W_1u_1^1).$$

Suppose that dW is negative in both cases i and ii, then we have, $W_2u_1^2 \frac{dy^1}{dt^1} > W_1u_1^1 - W_2u_1^2 > -W_1u_1^1 \frac{dy^2}{dt^2}$, but by the assumption that y is a normal good for both agents this equation is self-contradictory. Hence for at least one case dW must be positive. It follows that, for such a case, (dt^1, dt^2) could be set such that $dW = 0$ and $dt^1 + dt^2 > 0$. That is, household WTP is higher when only one agent contributes to the household good, compared to the both-contribute situation.

PROPOSITION 2. *Suppose A1 and A2. (i) Provided both individuals contribute to the household good, the sum of equilibrium individual WTP values is exactly twice JWTP. (ii) If only one individual contributes, then the sum of equilibrium individual WTP values is higher than JWTP.*

Proof. Part (i) arises from Warr's theorem – if the total contribution to the public by the household is the same in both cases, then the total remaining household income is the same, hence there is the same level of the household good in both cases and hence the same first order conditions. For part (ii), w.l.o.g. suppose that it is player 1 who makes no contribution to the household good. It follows that player 2's contribution is the same under the two scenarios and, consequently, that the

level of the household good y^2 is the same. However, under the equilibrium conjecture, player 1 assumes that player 2's contribution to the public good is zero, whereas in the JWTP case $t^2 > 0$. Since the household good is normal, then in the equilibrium WTP, y^2 (as conjectured by player 1) is higher than in the joint case. Thus, t^1 will also be higher in the equilibrium WTP case.

PROPOSITION 3. *Suppose A1 and A2 then (i) if both individuals contribute to the household good, the sum of the uniform charge equilibrium WTP values equals the JWTP; (ii) if only one person contributes to the household good, then the sum of the uniform charge equilibrium WTP values exceeds the JWTP provided that the contributor pays a higher charge for the public good in the joint case. When the non-contributor to the household good pays the higher charge, then JWTP exceeds the sum of the uniform charge equilibrium WTP values.*

Proof. As in the first proposition, (i) follows from Warr's theorem. In the second part of the proposition, suppose that w.l.o.g. player one makes no contribution. Note that as in proposition 1, the second individual's WTP is the same under the two scenarios (i.e. $t^{23} = t^{24}$) as is the level of the household good. First consider the situation when $t^{24} > t^{14}$. Suppose that $t^{13} \leq t^{14}$, then $t^{13} = t^{13} < t^{24}$ and hence the value of y^2 conjectured is higher in case 3 than actually occurs in case 4, implying $t^{13} > t^{14}$ – a contradiction. It follows that $t^{13} > t^{14}$. Now suppose that $t^{13} > t^{24}$, but then the conjectured value of y^2 would be lower than what actually occurs – implying that $t^{13} < t^{14}$. Again this is a contradiction and so $t^{24} = t^{23} > t^{14}$. If, in fact, $t^{24} < t^{14}$, then a similar argument establishes that $t^{14} > t^{13} > t^{23} = t^{24}$.

PROPOSITION 4. *Suppose A1 and A2 and S, then (i), if $y^{i*} > 0$ for both agents, then individual disequilibrium WTP is less than individual equilibrium WTP for both agents but the sum of individual disequilibrium WTP exceeds JWTP; (ii) if $y^{i*} = 0$ for one agent then disequilibrium WTP equals equilibrium WTP for that agent, while the sum of individual disequilibrium WTP exceeds JWTP.*

Proof. Before beginning the proof, it will be useful to have the following result:

LEMMA. *If $U^i(m^i - y^i - t^i, y^i + y^{-i}, z) = U^i(m^i - y^i - t^i, y^i + y^{-i}, z)$, y^i and y^i are chosen optimally and are both strictly positive, then $y^i + y^i = y^i + y^i$ and $t^i = t^i + (y^{-i} - y^i)$. If $y^i > 0$, but $y^i = 0$, then $y^i + y^i < y^i$ and $t^i > t^i + y^i$.*

Proof. When y^i and y^i are both strictly positive we have:

$$U^i(m^i - t^i - y^i, y^i + y^{-i}, z) = U^i(m^i - t^i - y^i, y^i + y^{-i}, z)$$

$$U_1^i(m^i - t^i - y^i, y^i + y^{-i}, z) = U_2^i(m^i - t^i - y^i, y^i + y^{-i}, z)$$

$$U_1^i(m^i - t^i - y^i, y^i + y^{-i}, z) = U_2^i(m^i - t^i - y^i, y^i + y^{-i}, z)$$

For these three equations to hold simultaneously, then $y^i + y^{-i} = y^i + y^{-i}$ and $t^i + y^i = t^i + y^i$. The first of these represents the first claim made in the statement of the lemma. Using it in the second condition yields the second claim. When $y^i > 0$, but $y^i = 0$, then the last equation is replaced by:

$$U_1^i(m^i - t^i, y^{-i}, z) > U_2^i(m^i - t^i, y^{-i}, z) \text{ and the concavity of } U \text{ rules out } y^i + y^{-i} \geq y^i.$$

For the main proof, we consider two cases, A and B. In case A $y^i > 0$ in all relevant situations, $i=1,2$. In case B $y^i = 0$ for one agent in at least one context.

Case A: $y^i > 0$, $i=1,2$. Part i of the proof. First note that, for the individual i , the two situations, equilibrium and disequilibrium, differ in the parameter y^i . Hence we need to find how changes in y^i alter t^i and then find the sign of $(y^{-i2} - y^{-i*})$. Note also that, by definition, $U^i(m^i - y^{i1} - t^{i1}, y^{i1} + y^{-i*}, z) = U^i(m^i - y^{i2} - t^{i2}, y^{i2} + y^{-i2}, z) = U^i(m^i - y^{i*}, y^{i*} + y^{-i*}, z)$. Consider the effects of changing y^i along the indifference surface joining the first of these two. By the lemma we have: $(t^{i2} - t^{i1}) = (y^{-i2} - y^{-i*})$. To find the sign of $(y^{-i2} - y^{-i*})$ we need to consider how y^i alters as z changes to z' , given t^i adjusts to keep $U^i = U^i(m^i - y^i, y^i + y^{-i*}, z)$ and (y^i, y^{-i}) represent a Nash equilibrium. Thus, differentiating the first order conditions for the Nash equilibrium:

$$U_{11}^i(dt^i + dy^i) - U_{12}^i(dy^i + dy^{-i}) - U_{13}^i dz + U_{12}^i(-dt^i - dy^i) + U_{22}^i(dy^i + dy^{-i}) + U_{23}^i dz = 0.$$

$$U_{11}^i(dy^{-i}) - U_{12}^i(dy^i + dy^{-i}) - U_{13}^i dz + U_{12}^i(-dy^{-i}) + U_{22}^i(dy^i + dy^{-i}) + U_{23}^i dz = 0.$$

Note that the dt^i does not appear in the second of these conditions because we are deriving the individual WTP for individual i , who conjectures that $-i$ faces no charge for the public good. In addition to these two equations we have the constant utility constraint. That is,

$$U_1^i(-dt^i - dy^i) + U_2^i(dy^i + dy^{-i}) + U_3^i dz = 0.$$

From this we get: $dt^i = dy^{-i} + dz U_3^i / U_1^i$. Using this to substitute out dt^i in the first equation produces:

$$dy^i \Delta^i + dy^{-i} \Delta^i - dz[-U_{13}^i + U_{23}^i + \frac{U_3^i}{U_1^i}(-U_{21}^i + U_{11}^i)] = 0.$$

Where $\Delta^i = (U_{11}^i - 2U_{12}^i + U_{22}^i)$, which is negative given the assumption of normality for y^i . In a similar manner we get,

$$dy^{-i} \Delta^{-i} + dy^i [U_{22}^{-i} - U_{12}^{-i}] - dz[-U_{13}^{-i} + U_{23}^{-i}] = 0.$$

Eliminating dy^i then yields,

$$dy^{-i} = -dz \left(-U_{13}^{-i} + U_{23}^{-i} - \left[\frac{U_{22}^{-i} - U_{12}^{-i}}{\Delta^{-i}} \right] \left[-U_{13}^{-i} + U_{23}^{-i} + \frac{U_3^{-i}}{U_1^{-i}}(-U_{21}^{-i} + U_{11}^{-i}) \right] \right) / (\Delta^{-i} - [U_{22}^{-i} - U_{12}^{-i}]).$$

The sign of this equation is ambiguous in general, but if S holds then $U_{13} - U_{23} U_1 / U_2 = 0$ and so $U_{13} = U_{23}$ when y^i is at an interior solution. Hence:

$$dy^{-i} = -dz \left(- \left[\frac{U_{22}^{-i} - U_{12}^{-i}}{\Delta^{-i}} \right] \left[\frac{U_3^{-i}}{U_1^{-i}}(-U_{21}^{-i} + U_{11}^{-i}) \right] \right) / (\Delta^{-i} - [U_{22}^{-i} - U_{12}^{-i}]).$$

The denominator is negative, given that y^i is normal. The terms on the numerator inside the parentheses are positive, hence overall dy^{-i} takes the same sign as dz . It follows that if z rises then $y^{-i2} > y^{-i*}$ and so $t^{i2} > t^{i1}$.

Part ii. We noted above that $U^i(m^i - y^{i1} - t^{i1}, y^{i1} + y^{-i*}, z) = U^i(m^i - y^{i2} - t^{i2}, y^{i2} + y^{-i2}, z)$ implies that, on the indifference surface joining the two, $dt^i = dy^i$, along the locus where y^i is chosen optimally. Since, along this locus, $-U_1^i + U_2^i = 0$ It follows that

$$U_{11}^i(dt^i + dy^i) - U_{12}^i(dy^i + dy^{-i}) + U_{12}^i(-dt^i - dy^i) + U_{22}^i(dy^i + dy^{-i}) = 0.$$

or,

$$U_{11}^i(dy^{-i} + dy^i) - U_{12}^i(dy^i + dy^{-i}) + U_{12}^i(-dy^{-i} - dy^i) + U_{22}^i(dy^i + dy^{-i}) = 0.$$

Since y is normal by assumption, this means that along the locus $dy^i + dy^{-i} = 0$. In other words, $y^{i1} + y^{-i*} = y^{i2} + y^{-i2}$. But since $y^{i2} + y^{-i2} = y^{i4} + y^{i4}$, we have that $y^{i1} + y^{i*} = y^{i2} + y^{i*}$. Hence, for all four measures of surplus (disequilibrium individual, equilibrium individual, uniform charge and joint) the level of Y is the same. Now consider t^{i2} such that the Nash equilibrium given $\mathbf{t} = (t^{i1}, t^{i2})$ yields $y^1 = y^{i1}$ and $y^1 + y^2 = y^{i4} + y^{i4}$. By Warr's theorem, therefore $t^{i1} + t^{i2} = \text{JWTP}$, but $t^{i2} < t^{i1}$ (if otherwise then $y^2 \leq y^{i2}$, implying $y^{i1} \geq y^{i*}$, when we have established the converse above) and so $t^{i1} + t^{i2} > \text{JWTP}$.

Case B. $y^i = 0$, for one agent in one context. The following table sets out the possible configurations. A zero entry indicates that the relevant y variable is equal to zero, a + sign indicates that the y variable is positive. Certain combinations of variables are not possible and hence are omitted. In particular, if $y^1 = 0$, then $y^2 = 0$ and if $y^{i*} = 0$, then $y^1 = 0$ and if $y^2 > 0$, then $y^4 > 0$. This leaves seven cases (out of a possible sixteen), one of which is Case A, where all relevant entries for y are positive.

y^i	y^{i1}	y^{i2}	y^{i4}	Proof
0	0	0	0	$y^{i1} = y^{i2} = 0$ implies that $y^{-i1} = y^{-i2}$, so $t^{i1} = t^{i2}$; $t^{i4} > 0$ implies $y^{i4} < y^{-i2}$, so $t^{i2} > t^{i4}$ while $t^{-i2} = t^{-i4}$. [Case B1]
0	0	0	+	$y^{i1} = y^{i2} = 0$ implies that $y^{-i1} = y^{-i2}$, so $t^{i1} = t^{i2}$; $t^{i4} > 0$ implies $y^{i4} < y^{-i2}$. Meanwhile optimisation by i implies $U_1^i(m^i - t^{i4} - y^{i4}, y^{i4} + y^{-i4}, z^i) = U_2^i(m^i - t^{i4} - y^{i4}, y^{i4} + y^{-i4}, z^i)$ and $U_1^i(m^i - t^{i2}, y^{-i2}, z^i) > U_2^i(m^i - t^{i2}, y^{-i2}, z^i)$. The concavity of U implies that these are contradictory if $y^{-i4} + y^{-i4} \geq y^{-i2}$ because then $t^{i2} \leq t^{i4} + y^{i4}$. Hence, $y^{-i4} + y^{-i4} < y^{-i2}$ and so $t^{i2} > t^{i4}$. For the second part, the lemma establishes that $t^{i1} > t^{i4} + y^{i4}$ and that $t^{24} + y^{24} = t^{21} + y^{21}$ while $y^{14} + y^{24} = y^{21}$. Putting these together yields $t^{i1} + t^{21} > t^{i4} + t^{24} + y^{24} - y^{21} + y^{14} = t^{i4} + t^{24}$. [Case B2]
+	0	0	0	Same argument as in Case B1.
+	0	0	+	Same argument as in Case B2.
+	+	0	0	Part i has the same argument as in Case B1. For the second part, note that the lemma implies that $t^{24} = t^{21} - y^{1*}$ and that $t^{i1} < t^{i1} + (y^{24} - y^{2*})$. Thus, $t^{i4} + t^{24} < t^{i1} + t^{21} + (y^{24} - y^{2*} - y^{1*})$. The term in parenthesis is negative and thus the sum of disequilibrium household WTP exceeds JWTP.
+	+	0	+	Same argument as in Case B2.
+	+	+	+	Case A above.