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What Can I Get For It? The Relationship Between the Choice Equivalent, Willingness to Accept and Willingness to Pay

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Abstract: We hypothesise and confirm a novel empirical result concerning the willingness to accept (WTA)-willingness to pay (WTP) disparity. Employing data from what has become the classic experimental design, we reveal systematic variation in the relative magnitudes of three valuations: WTA, WTP and choice equivalent (CE). Individuals with low CE relative to others set a proportionally higher WTA, while those with high CE set a proportionally lower WTP. The effect size is substantial in relation to the WTA-WTP disparity itself. These results are predicted by a model in which subjects behave as if maximising surplus over a sequence of exchange encounters, as typifies real exchanges outside the laboratory. They are at odds with models based on loss aversion, which either predict constant relativities between the three valuations or the opposite of the pattern observed.

Keywords: Endowment effect, willingness to pay, willingness to accept, loss aversion

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1. Introduction

There remains no agreed explanation for the finding that experimental subjects and survey respondents generally set a minimum selling price for an item that is two or more times higher than the maximum those without the same item will pay to acquire it. Failure to identify decisively the cause of this large gap between willingness-to-accept (WTA) and willingness-to-pay (WTP) is problematic. As well as implying shortcomings in our understanding of simple exchanges, which are economically fundamental, the WTA-WTP disparity presents challenges for important areas of applied economics, including assessment of legal compensation and cost benefit analysis (see, for example, OECD, 2006). The phenomenon has also been influential in the development of alternative theories of preference and consumer choice.

Kahneman, Knetsch and Thaler (1990) (hereafter KKT) developed what has become a classic experimental design to investigate this phenomenon. In incentive compatible exchanges of ordinary consumer items, KKT revealed systematic differences between average WTA, WTP and the choice equivalent (CE),[1] defined as the minimum monetary amount subjects choose over the item in a binary choice. The present paper hypothesises and confirms that the data produced by KKT's widely cited design contain a heretofore undetected regularity. Furthermore, the empirical pattern uncovered is not consistent with current explanations for the WTA-WTP disparity (including Tversky and Kahneman, 1991; Köszegi and Rabin, 2005; Loomes, Orr and Sugden, 2009; Kling, List and Zhao, 2013; Isoni, 2011; Weaver and Frederick, 2012).[2] Using data from seven published experiments, which provide 23 sets of observations obtained via the classic design,[3] we reveal systematic variation in the relationship between WTA, WTP and CE, which suggests that subjects take account of how

[1] An alternative expression for this valuation, "equivalent gain", is also sometimes used.

[2] Note that, although in widespread use, the expression "endowment effect" has become controversial (cf. Plott and Zeiler, 2005). Ambiguity now exists as to whether it refers to an empirical phenomenon or an associated explanation. Furthermore, the expression is sometimes used to refer to the experimental design of Knetsch (1989), which demonstrates resistance to exchange in non-monetary transactions and is not our present focus. We therefore employ the term "endowment effect" sparingly here to facilitate scientific precision. Our focus is the WTA-WTP disparity, which we describe as such.

[3] The raw data were obtained via written requests to corresponding authors of four studies identified as useful for testing our predictions. The two primary considerations were to obtain data that, first, had been gathered using the method of KKT and, second, included not only WTA and WTP valuations, but also the "choice equivalent", CE. We obtained raw data and assistance in interpreting it from the corresponding authors of Bateman et al. (2005) and Novemsky and Kahneman (2005), and we are grateful for their cooperation and assistance. The original data from Kahneman et al. (1990) were unfortunately destroyed by fire. A repeated request was made in respect of the fourth study, which was not responded to. Drafts of this paper were sent to the corresponding authors who supplied data and to Daniel Kahneman, who is an author of both papers, to ensure that the data and associated studies had been handled and described appropriately.

they value the item relative to the valuations of others. The findings suggest that subjects consider not only their own preferences, but also their perceptions of what others will pay or accept.

Before proceeding to describe theory and empirics, some discussion is merited in relation to scientific approach. In the present paper we test hypotheses by exploiting the existing body of data, rather than by undertaking a further adaptation of the original KKT experiment. This decision was taken for three reasons. Firstly, the primary goal for any theory of the WTA-WTP disparity must be consistency with results obtained in the most replicated studies. In a broad review of the substantial progress made by experimental economics in recent years, Bardsley et al. (2010) argue that the regularity of the effect produced by the KKT design means that it should be considered an "experimental exhibit". Consistency with data from this exhibit must, therefore, be a priority for any theory. Secondly, the pattern we test with data from the original KKT design is a unique prediction, in that it appears to be inconsistent with other prevailing theories (see Section 4). In their review, Bardsley et al. (2010) conclude that the complexity of economic experiments makes decisive experimental tests elusive because rarely can a test statistic be identified with a given theoretical construct uniquely, with all other possibilities equalised. This generalisation may be particularly relevant for the WTA-WTP disparity, which has inspired a proliferation of models that hinge on unobserved constructs such as reference states, misconceptions, taste uncertainty and subjective option values (see Section 2). Since we have developed a model that makes a unique prediction about existing data, it is therefore scientifically appropriate to test that prediction. Thirdly, because they exploit data from multiple studies, our findings are based on the behaviour of subject pools in more than one country, trading a range of consumer items, recorded by different experimenters, all of whom were unaware at the time of the hypotheses we test. In effect, therefore, our empirical test is double-blind. These benefits are important given the claim of Bateman et al. (2005, p. 1577) that significant differences in the WTA-WTP disparity might exist across subject pools or between nationalities, and concerns about the potential influence in WTA-WTP studies of experimenter demand (see Engelmann and Hollard, 2010, p. 2017, footnote 10; List, 2011, p. 316)

The preceding paragraph forms the essential scientific logic of the present paper. Good theories should explain primary replicated phenomena, make novel predictions, and generalise across contexts. Hence, the present study takes the opportunity to test new hypotheses on existing data from multiple studies.

Section 2 summarises the debate surrounding the WTA-WTP gap and motivates our exploration of agents' perceptions of what others may be prepared to pay or accept. Section 3 derives two novel predictions about patterns in existing data. Section 4 discusses contrasting predictions from other models. Section 5 tests the hypotheses and finds that they hold. Section 6 discusses the significance of the findings.

2. Background

The predominant theoretical perspective on the WTA-WTP disparity has held that preferences are reference dependent, meaning that they are systematically modified according to a reference state, initially identified with the individual's current endowment (Tversky and Kahenman 1991). Losses relative to the reference state are weighted more heavily than equivalent gains, i.e. individuals are loss averse, in violation of the neoclassical independence axiom. In the context of the present paper, it is important to note that reference dependence implies that the relationship between WTA, WTP and CE is governed by the extent of loss aversion for money. If loss aversion for money is small or non-existent, CE approximates WTP; if it is substantial, CE lies between WTP and WTA.

Others have been less quick to abandon neoclassical assumptions, in part because while the WTA-WTP gap has been recorded many times, it varies in magnitude in different contexts. For instance, it is reduced or extinguished in experiments that employ certain combinations of repeated trading rounds, training in value elicitation methods and/or trade, or other more subtle manipulations of experimental procedures (e.g. Shogren et al. 1994; Franciosi et al. 1996; Plott and Zeiler, 2005; Engelmann and Hollard, 2010). An influential contribution is List (2003; see also List, 2006), who showed that the WTA-WTP gap was attenuated for dealers at a sportscard show. List concluded that the disparity is a characteristic of inexperienced traders, with preferences converging to the neoclassical model with experience.

To account for such variation, reference dependent models require additional degrees of freedom. Two alternatives have been proposed. Köszegi and Rabin (2006) contend that the reference state is defined by expectations, such that experience or experimental procedures that increase the expectation of trade will reduce loss aversion and, therefore, the WTA-WTP gap also. Loomes et al. (2009) suggest instead that the WTA-WTP disparity is determined by uncertainty about future preferences, with greater weight given to future "taste states" that entail losses, resulting in attenuation of the WTA-WTP gap where experience or experimental procedures reduce uncertainty. To date, manipulations of the KKT experimental design that have aimed directly to alter expectations of trade have produce ambiguous results (Ericson and Fuster, 2011; Heffetz and List, 2013). No theory presently provides a consistent explanation for why the experimental procedures introduced by Plott and Zeiler (2005) extinguish the effect (see Plott and Zeiler, 2011; Isoni, Loomes and Sugden, 2011).

Reference dependent theories presume that the valuations elicited from subjects in experiments directly reflect preferences for the item being traded – that being a buyer (WTP), seller (WTA) or chooser (CE) alters preferences. An alternative is that the process of buying, selling or choosing introduces other considerations into the agent's decision-making. Kling et al. (2013) propose that subjects take into account the option values of buying or selling at a later stage, and that cognitive dissonance results in sellers placing a greater value on the option value of selling later, thus raising WTA. Isoni (2011) and Weaver and Frederick, (2012) instead introduce the idea that agents get utility both from consuming the item and from the transaction itself, such that good deals result in higher overall utility.

Lunn and Lunn (2014) offer an alternative model that also does not assume loss aversion and has some commonalities with the latter three approaches. The main innovation is to propose that when buyers and sellers determine their WTA and WTP, they consider not only their own preferences but also valuations of potential trading partners. The rationale for this behaviour is that it represents the typical exchange situation in real markets outside the laboratory, where the decision faced is usually whether to trade immediately or to hold out for a better deal. Trading decisions generally require agents to form a perception of the distribution of potential deals and to determine their willingness to exchange relative to it, rather than to compare the utilities of an item to a single price.[4] In real markets, a seller asks "What can I get for it?"; a buyer asks "What can I get one for?". Thus, subjects may instinctively apply criteria for willingness to exchange that they use outside the laboratory to the situation they face in experiments that follow the KKT design. They behave as if they are at the start of a potential sequence of trading opportunities, when in fact they are in a one-shot market that will clear at a single price. The overriding intuition behind our account, therefore, is that agents simply extend a logic that they use successfully outside the laboratory to a one-shot experiment where, effectively, it backfires.

The remainder of this paper derives and tests a unique hypothesis of this latter model, which following Marr (1982) is referred to as the 'Computational Theory of Exchange' (hereafter CTE). Lunn and Lunn (2014) provide extensive discussion of how the CTE model relates to other exchange phenomena, focussing primarily on those relating to the endowment effect. The CTE model is consistent with self-reports of how WTA and WTP are set (Brown, 2005) and with findings showing that willingness to exchange is correlated with perceptions of what others will pay or accept (e.g. Van Boven, Dunning and Loewenstien, 2000), related to perceptions of market prices (Mazar et al., 2010; Weaver and Frederick, 2012), adjusted in experimental auctions where subjects get feedback on what others will pay or accept (e.g. Franciosi et al., 1996; Shogren et al., 1994), and altered by directly manipulating the likelihood of future exchanges (Kling et al., 2013). The CTE model may also provide insights into why the WTA-WTP disparity is affected by the experimental procedures of Plott and Zeiler (2005) and by extensive trading experience (List, 2003).

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[4] Reviewing several decades of literature, Baye, Morgan and Scholten (2006) show how substantial price dispersion is a ubiquitous characteristic of real markets. This remains the case even in modern competitive markets with apparently near costless price comparison.

The CTE model implies that, to the extent that subjects can place their own valuation within the population distribution of valuations, the relationships between WTA, WTP and CE should vary systematically across that distribution. This empirical conjecture is attractive because, as we will show, the predicted pattern is not consistent with other models, and can be tested on experimental data from multiple studies using the original KKT design.

3. Derivation of Predictions

3.1 The CTE Model

The CTE model is a highly generalised model of exchange. It has a similar structure to many modern consumer search models, yet applies to both buyers and sellers and requires no assumptions about price distributions, the completeness of information, or preferences over risk. The full model, with extensions, boundary conditions and proofs, can be found in Lunn and Lunn (2014); here we present only what is essential to derive the hypotheses for test.

Agents face sequential opportunities to trade, which come at a cost. Consider a seller who owns a good with a private value, x, and perceives the distribution of likely bids from potential buyers, Y, with mean μ_Y and variance σ_Y^2. The seller sets WTA as if they expect to encounter bids in sequence $\{Y_1, Y_2, \ldots, Y_j, \ldots\}$. Each bid entails a (small) cost, c, which we call the "encounter cost".[5] The seller sets WTA = x + α, where α > 0 (as the seller will not sell at a loss), such that α corresponds to the minimum acceptable margin over and above the seller's own valuation. Thus, the seller chooses α to maximise expected surplus:

$$E(S) = E(Y|Y > x + \alpha) - x - \frac{c}{\Pr(Y > x + \alpha)} \qquad (1).$$

This set-up centres on a trade-off between holding out for a better ultimate price and incurring incremental costs. Lunn and Lunn (2014) prove that, provided the encounter cost is below an upper bound, the solution can be derived for any continuous distribution such that α* satisfies

$$c = \int_{x+\alpha^*}^{\infty} \big(1\text{-}F(y)\big)dy \qquad (2),$$

[5] This cost can be conceived of as a search cost, but we do not describe it as such for reasons of generality. Active search is not necessary, while the cost could also reflect delay to final consumption, risks associated with encounters, or the cognitive load associated with considering more offers.

where F(y) is the cumulative distribution function of Y. In Equation 2, α^* is decreasing in x and c. Further, where Y is unimodal and continuous, with a steadily decreasing probability of receiving bids higher than μ_y, α^* is increasing in $\sigma_{y.}$

A symmetric set-up applies to the buyer, who sets WTP = x – β, where β > 0. For a perceived distribution of offers Z, with mean μ_z and variance σ_z^2, the buyer's problem is to set β to maximise

$$E(S) = x - E(Z|Z < x - \beta) - \frac{c}{\Pr(Z < x - \beta)} \qquad (3),$$

which (subject to an upper bound on c) yields

$$c = \int_{-\infty}^{x-\beta^*} F(z)dz \qquad (4),$$

where F(z) is the cumulative distribution function of Z. This time, β^* is increasing in x, decreasing in c, and increasing in σ_z.

3.2 Predictions for WTA, WTP and CE

The model straightforwardly results in a WTA-WTP disparity such that WTA/WTP = (x + α)/(x – β), but it also has implications for the variation in WTA and WTP across individuals with different valuations, x_i. Consider two sellers with valuations x_1 and x_2. If the individuals are otherwise identical, such that they perceive the same distributions of bids and offers and face the same encounter cost, then $x_1 + \alpha_1^* = x_2 + \alpha_2^*$ and $x_1 - \beta_1^* = x_2 - \beta_2^*$. Hence WTA/WTP is the same for both agents. However, if $x_1 < x_2$, then $\alpha_1^* > \alpha_2^*$ and $\beta_1^* < \beta_2^*$ and, more importantly for present purposes

$$(x_1 + \alpha_1^*)/x_1 > (x_2 + \alpha_2^*)/x_2 \qquad (5)$$

and

$$x_1/(x_1 - \beta_1^*) < x_2/(x_2 - \beta_2^*) \qquad (6).$$

Equations 5 and 6 form the basis of our predictions. According to the model, x represents the private valuation, such that in a binary choice the individual is indifferent between x and the item. That is, x equates to CE, which always lies between WTA and WTP. Consequently, Equation 5 amounts to a counterintuitive claim. The ratio of WTA to CE, which is sometimes used as a measure of resistance to exchange, should be greater for individuals who value the good least, all else equal, relative to other individuals. That is, WTA/CE should be decreasing in CE. Similarly, according to Equation 6, CE/WTP should be increasing in CE. Again, this is initially counterintuitive, because it implies that individuals who value the good most should be willing to pay a smaller proportion of their valuation. These predictions appear counterintuitive only from the perspective of individual preferences considered in isolation, in line with accounts based on reference dependence. If, instead, agents consider how they value an item relative to others, the predictions make sense.

According to the CTE model, WTA (WTP) is determined by Y (Z) and c, irrespective of xi. In practice, there will be substantial variation across individuals in Y, Z and c, leading to similar substantial variation in WTA (WTP). In fact, empirical evidence not only supports variation in perceptions of the valuations of others, it also suggests that Y (Z) is likely to be biased in the direction of xi, i.e. those with low valuations may assume lower valuations among others too (Van Boven et al., 2000; Frederick, 2012), in line with the broader psychological phenomenon of "false consensus bias" (Ross, Green and House, 1977). Such correlations would tend to weaken the predicted relationships described in Equations 5 and 6. It is hence important to establish the implications for our model and predictions. As a robustness check, we therefore conducted model simulations, using Equations 2 and 4 to solve for WTA and WTP, for empirically realistic valuation distributions, a range of encounter costs, and correlations between x and Y (Z) of up to 0.7. These simulations (see Appendix A) show that it would require an extremely strong perceptual bias to nullify the predicted relationships and that our predictions are hence robust to correlation between private valuations and perceptions of others' valuations.

4. Predictions of Existing Models

Before presenting empirics, this section aims carefully to derive equivalent empirical predictions from models briefly reviewed in Section 2.

4.1 Prediction of Tversky and Kahneman (1991)

In Tversky and Kahneman (1991), the WTA-WTP gap is determined by the extent of loss aversion implied by the shape of the value function according to Prospect Theory (Kahneman and Tversky 1979). Since the shape of this value function is not systematically related to an individual's location within the population distribution of valuations, the model predicts no variation in either WTA/CE or CE/WTP with CE. Tversky and Kahneman (also Novemsky and Kahneman, 2005) further propose that loss aversion does not apply to goods intended for resale or to money. Thus, this version of the theory also implies that CE/WTP = 1.

4.2 Prediction of Köszegi and Rabin (2006)

In this later reference dependent formulation, the gain-loss function also "satisfies the properties of Kahneman and Tversky's (1979) value function" (Köszegi and Rabin, 2006, p. 1134). However, this model permits greater variation in the WTA-WTP disparity because the reference state, which determines the degree of loss aversion, is determined by expectations of trade rather than endowments. All else equal, sellers with low CE will be inclined to perceive that others tend to value the good more than they do, while sellers with high CE will be inclined to perceive that others tend to value the good less than they do. Consequently, those with low CE should have a greater expectation of selling than those with high CE. Since, according to the model, this expectation leads them also to experience less loss aversion, WTA/CE should be increasing in CE. Similarly, buyers with high CE should have more expectation of buying and hence experience greater loss aversion if they fail to buy, leading them to be willing to pay a higher price. Thus, CE/WTP should be decreasing in CE. Consequently, the model predicts the opposite of the CTE model.

4.3 Prediction of Loomes et al. (2009)

Loomes et al. (2009) propose that WTA-WTP gaps result from uncertainty regarding utility at the time of final consumption, which varies according to the agent's "taste state". Formally, the subjective value of moving from reference bundle z to alternative consumption bundle x is

$$v(x,z) = \sum_{h} \{\pi(s_h)\varphi[u_h(x) - u_h(z)]\} \qquad (7),$$

where $\pi(s_h)$ is the subjective probability of taste state s_h, which entails the utility function $u_h(.)$ over x and z, but where $\phi(.)$ is concave, such that utility losses are ultimately weighted more heavily than equivalent utility gains. If sufficient taste states exist in which $u_h(x) - u_h(z) < 0$, v(x, z) can be negative even where bundle x has higher expected utility than bundle z.

In Appendix B, we use this formulation to derive an expression for CE and to show that for a given set of possible taste states WTA/CE is (weakly) increasing in CE. Intuitively, given two agents with the same endowments and taste states, the agent with the higher marginal utility for the item (i.e. higher CE) has a greater or equal probability of final utility loss when selling and, therefore, a greater or equal WTA/CE. By similarity, CE/WTP is (weakly) decreasing in CE. Again, therefore, this model predicts the opposite of the CTE model.

4.4 Prediction of Kling, List and Zhao (2013)

The model of Kling et al. (2013) is closer to the CTE in that it shares the idea that subjects behave as if the experimental situation presents the first of more than one trading opportunity, rather than a one-shot game with pay-offs consisting of money or final consumption. Kling et al.'s model can be summarised as valuation + O_{buying} = E(value of item) + $O_{selling}$ (8),

where the valuation is either WTP or WTA and Obuying and Oselling are the option values of trying to buy later and trying to sell later respectively. A WTA-WTP disparity hinges on buyers and sellers possessing asymmetric perceptions of option values. The logic is that the option value of selling is generally low, because most people lack selling experience, but that for those cast in the role of sellers, cognitive dissonance increases the option value of selling.

Thus, subjects asked for their CE have the same option values as buyers and the model therefore predicts WTP = CE. Meanwhile, any prediction about how WTA/CE varies with CE depends on how the two option values are assumed to scale with expected value. If option values are proportionally smaller for individuals with higher expected values, WTA/CE could in principle decrease with CE, though there is no obvious rationale for this.[6] Thus, this model is ambiguous with respect to variation in WTA/CE, but unambiguously predicts that CE/WTP = 1.

4.5 Prediction of Transaction Utility Models

Two recent models propose that agents consider not only the private value of the item being traded, but also whether they get a good deal relative to an expected transaction price (Isoni, 2011) or a market price (Weaver and Frederick, 2012). These models could, with certain additional assumptions, predict the same pattern of variation in WTA/CE and CE/WTP with CE as the CTE model, but they also make a more straightforward prediction about the relationship between CE and WTP. Because buyers get positive utility from buying below the expected (or the market) price, the models predict that WTP>CE for all those whose CE is lower than the expected (or market) price, which according to empirical data is the large majority (Weaver and Frederick, 2012). This contrasts with the CTE model, which predicts that CE>WTP.

5. Empirics

5.1 Empirical Hypotheses

The classic experimental paradigm is a between-subject design and this suffices to test the predictions. The model implies that individuals with lower CE will, all else equal, have higher WTA/CE and lower CE/WTP. Hence, once the valuation distributions are matched by quantile, we hypothesise that WTP<CE<WTA, while WTA/CE should be greater for lower quantiles and CE/WTP should be greater for higher quantiles. More formally:

[6] There is some ambiguity in Kling et al. (2013) with respect to option values, which are identified at different points with transaction costs, "difficulty" of buying/selling, and additional time to reduce the uncertainty surrounding perceptions of value and market price. Depending which of these definitions is adopted, an argument can be made either way regarding whether option values scale with expected value.

Hypothesis 1: When the distributions of willingness-to-accept (WTA) and choice equivalent (CE) valuations are matched by quantile, WTA/CE is lower for upper quantiles.

Hypothesis 2: When the distributions of willingness-to-pay (WTP) and choice equivalent (CE) valuations are matched by quantile, CE/WTP is higher for upper quantiles.

Given the small sample sizes of laboratory experiments, we base our main analysis on two quantiles. We divide paired sets of WTA-CE (CE-WTP) observations either side of the median, then compare WTA/CE (CE/WTP) separately for the bottom (Q1) and top (Q2) quantile. Note that this between-subjects test using just two quantiles is conservative, because it is likely to dampen the effects we hypothesise relative to an equivalent (hypothetical) within-subjects comparison. The between-subjects test assumes that changing the valuation from CE to WTA or WTP is order preserving. Yet to the extent that this assumption does not hold, both hypothesised relationships will tend to be underestimated. By ruling out the possibility that subjects in the upper quantile for CE migrate to the lower quantile for WTA or WTP, the between-subjects analysis is liable to increase WTA/CE and decrease CE/WTP for subjects in the upper CE quantile, while the opposite applies to the lower quantile. (We show this algebraically in Appendix C).

After performing our main test of the two hypotheses using just two quantiles, we shed further light on the magnitude of the relationships by matching up realisations of order statistics to pool data across experiments, which allows us to estimate variation in WTA/CE and CE/WTP across five quantiles.

5.2 Data

The raw valuation data are from a range of experiments reported in Novemsky and Kahneman (2005) and Bateman et al. (2005). The scope of these studies allows us to test our hypotheses with nine paired sets of WTA-CE valuations and five paired sets of CE-WTP valuations, all obtained using the original KKT experimental design.[7] Both WTA-CE and CE-WTP comparisons involve at least three different consumer items (mugs, chocolate and pens) and subjects located in three different countries (USA, Canada, UK). The five sets of CE valuations in the CE-WTP comparisons also feature in the WTA-CE comparisons. A summary of the data is provided in Table 1, together with mean valuations and sample sizes. The labelling of the experiments and treatments is preserved from the original studies.

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[7] Minor differences include: the exact wording of instructions; whether subjects were confronted with a list of prices on paper or a sequence of choices on a computer screen; what mechanism determined the final exchange price; and whether subjects also completed other tasks during the experimental session. Details are provided in the original reports.

Before conducting additional analyses, we ensured that we could use the raw data to reproduce the published results, which we managed without difficulty for all 23 sets of observations. It is noteworthy at this stage that for only one of five possible CE-WTP comparisons is mean CE less than mean WTP. In the other four, mean CE is greater than mean WTP, as was the case in the two experiments of KKT and the replication of KKT undertaken by Franciosi et al. (1996). This relationship is contrary to that predicted by models based on transaction utility.

Table 1: Summary of data

	Bateman *et al*. (2005)			Novemsky and Kahneman (2005)					
	MG	MG*	GM	Exp 1	Exp 2	Exp 4	Exp 5	Exp 7	Exp 8
Good	Vouchers for chocolate	Chocolate	£1.00[†]	Mug	Pen	Chocolate	Chocolate	Pen	Chocolate
Mean CE	£2.85	£2.92	8.35	\$3.31	\$2.50	\$1.79	\$3.10	\$3.19	\$6.24
CE sample	40	55	40	25	53	36	51	38	33
Mean WTA	£3.09	£3.59	10.45	\$7.51	\$4.22	\$2.25	\$4.78	\$3.29	\$11.24
WTA sample	40	52	40	25	54	33	54	45	34
Mean WTP	£1.52	-	-	\$2.82	\$1.44	-	-	\$3.60	\$4.51
WTP sample	40	-	-	23	55	-	-	41	33

[†] In this case, subjects in the WTA condition were endowed with one pound sterling and various prices bid in numbers of chocolates, while subjects in the CE condition chose between a gain of one pound or varying numbers of chocolates. The unit of currency here is therefore the chocolate.

5.3 Two-Quantile Statistical Method

There is divergence within the literature regarding whether to compare median or mean valuations. The median is subject to significant measurement error caused by the tendency for valuations to be drawn towards prominent round numbers (e.g. \$2.00, \$5.00, etc.).[8] Given this and the need to make separate comparisons for upper and lower quantiles, which halves the samples, the priority is to minimise measurement error and maximise available variation in the data. Thus, the superior statistical analysis is a comparison of means. However, a slight bias results in some experiments where a small number of subjects had valuations above the maximum price available on the response sheet, i.e. those who even at the highest listed price would still buy (WTP condition), refuse to sell (WTA), or choose the item rather than the money (CE). Overall, 38 (4%) of the total of 940 subjects recorded such valuations. The existence of this upper limit could marginally bias mean valuations of the upper quantile (Q2) downwards. To nullify the problem, for each pair-wise comparison, we discard observations at the maximum price and also discard the corresponding top

[8] To see this, consider conducting the same experiment with two different currencies, such that prices corresponding to prominent round numbers shift position within the valuation distribution. Assuming these prices attract valuations symmetrically (i.e. from above and below), the potential impact of the currency switch on the median would be considerably greater than its potential impact on the mean.

percentiles of the comparison set of observations. We then define the lower quantile, Q1, to be those observations below the median of the remaining slightly truncated distribution of valuations, and the upper quantile, Q2, to be those observations above the median. While this solution aims to negate a small bias, our results are not sensitive to the procedure.[9]

To illustrate, Table 2 shows the detailed calculation for the MG* comparison of WTA and CE from Bateman et al. (2005), which involved subjects stating CE or WTA for a box of chocolates. The data are expressed as frequencies at valuations that correspond to the midpoints of intervals of £0.30, derived from a list of 26 prices with a minimum of £0.00 and a maximum of £7.50. Two WTA subjects would not sell at this maximum price. We exclude these observations and calculate the mean of the lowest 25 (Q1) and the highest 25 (Q2) remaining observations, then compare these to the mean of the lowest 26.44 and highest 26.44 CE observations, which are the matching CE valuations. For Q1, WTA/CE is 1.40, while for Q2 it is 1.14.

Table 2: Raw frequency data and calculation of WTA/CE for Q1 and Q2 in comparison MG*, derived from Bateman *et al*. (2005)

£	WTA valuations	CE valuations	£	WTA valuations	CE valuations
0.15	0	2	4.05	11	5
0.45	0	0	4.35	1	1
0.75	1	1	4.65	0	0
1.05	2	8	4.95	8	10
1.35	2	1	5.25	0	0
1.65	2	0	5.55	1	0
1.95	2	6	5.85	1	1
2.25	3	3	6.15	0	0
2.55	2	4	6.45	1	0
2.85	7	6	6.75	0	0
3.15	2	2	7.05	0	0
3.45	3	3	7.35	0	0
3.75	1	2	MAX	2	0
			Obs.	52	55

	Mean WTA	Mean CE	WTA/CE
Q1	£57.75/25 = £2.31	£43.55/26.44 = £1.65	1.40
Q2	£113.55/25 = £4.54	£105.70/26.44 = £4.00	1.14

9 Specifically, the results are unchanged by simply including the maximum valuations. An additional sensitivity analysis reveals that even adding 25% to all maximum valuations, which is unrealistically high given the shape of the valuation distributions, makes no difference to the direction of the result in any experiment, and hence would not alter the p-values we report.

5.4 Two-Quantile Results

Figure 1 shows the results when this analysis is conducted for the nine possible WTA-CE comparisons. WTA/CE is greater for the lower quantile, Q1, in eight of the nine comparisons. Interestingly, the one comparison in which WTA/CE is greater for the upper quantile, Q2, is the condition (GM) in which prices were expressed in chocolates and subjects had to set their price for buying, selling or choosing £1.[10] The likelihood of observing a higher WTA/CE ratio for Q1 than Q2 in at least eight out of nine experiments if, in fact, the probability of such an observation were 0.5, is 10/512 (p=0.020). The data, therefore, support Hypothesis 1.

Figure 1: Comparison of WTA/CE for low and high quantiles. WTA/CE is greater for the lower quantile (Q1) in eight of nine paired sets of observations.

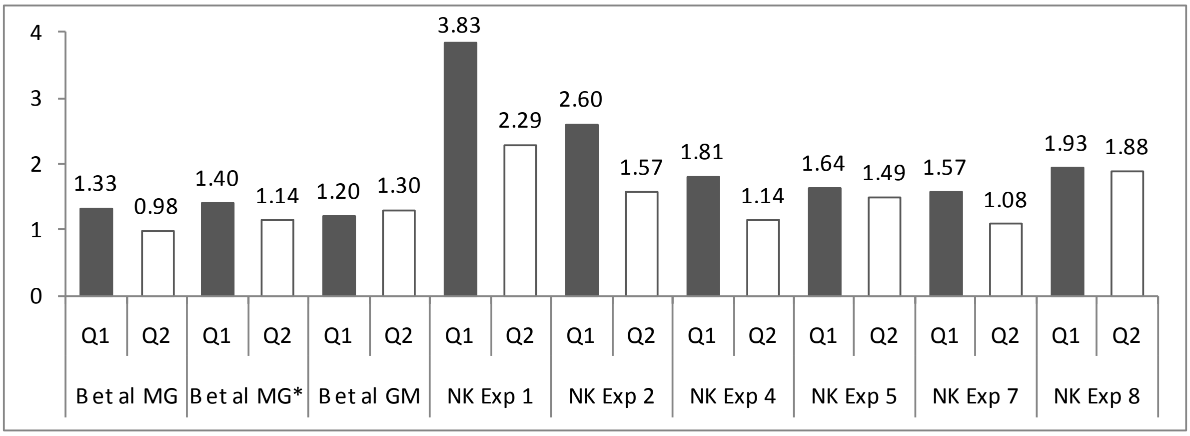
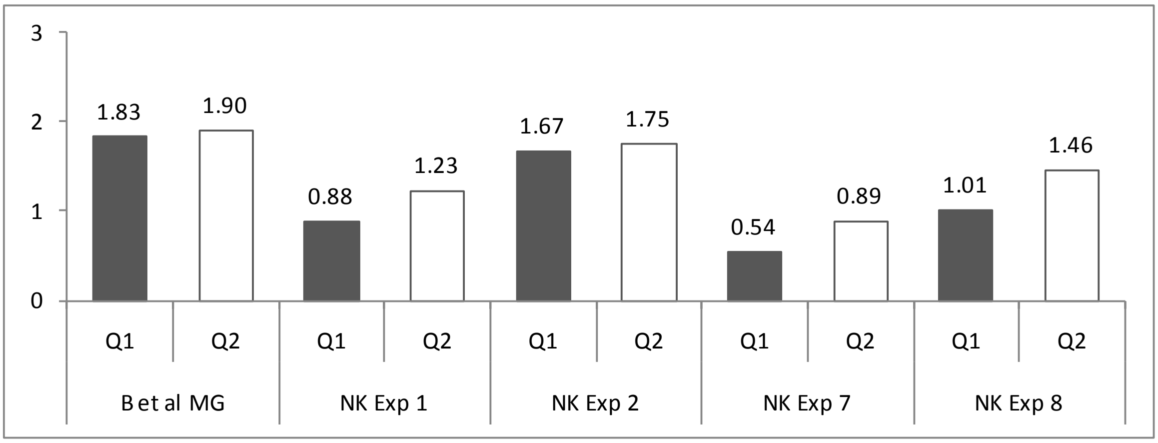


Figure 2 reveals the outcome of the CE-WTP comparison. In this case, CE/WTP is greater in Q2 in all five comparisons. The chance of observing this if, in fact, the probability of CE/WTP being greater for Q2 were 0.5, is 1/32 (p=0.031). These results support Hypothesis 2. Taken together, the two-quantile comparisons therefore provide clear support for both hypotheses.[11]

[10] In the original study, Bateman et al. report different implicit preferences when the “response mode” was chocolates instead of money, with subjects apparently valuing chocolate much less relative to money once valuations were requested in units of chocolate. This might or might not be related to our findings, but does suggest that the unusual nature of the task also had an unusual impact on the setting of CE and WTA.

[11] The two p-values associated with Hypotheses 1 and 2 should not be regarded as independent, because five sets of CE observations are common to both WTA-CE comparisons and CE-WTP comparisons. Note, however, that any statistical variation that increases mean CE for Q1 relative to Q2 and hence increases the probability that the data conform to Hypothesis 1, simultaneously decreases the probability that the data support Hypothesis 2.

Figure 2: Comparison of CE/WTP for low and high quantiles. CE/WTP is greater for the higher quantile (Q2) in each of five paired sets of observations.



5.5 Effect Magnitude

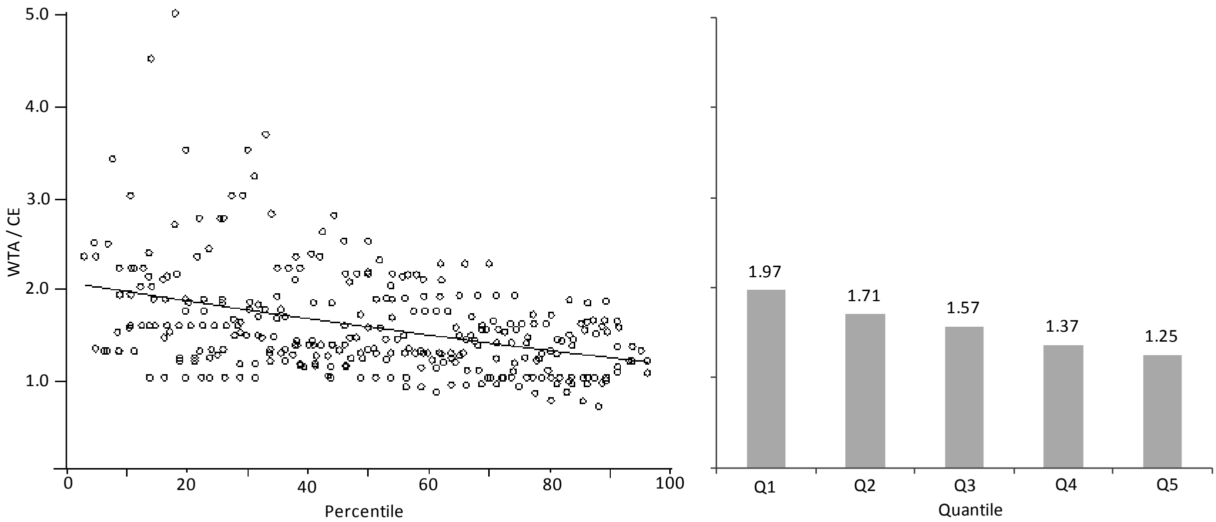
The results presented thus far are consistent with the predictions of CTE model and run contrary to existing accounts. Although this initially implies support for the CTE model, there are at least two alternative ways one might interpret the two-quantile results. First, the empirical test we have conducted is not a direct test of the mechanism of the CTE model. Rather, the prediction we have confirmed is an indirect implication of the model – albeit one that is at odds with other models. It is therefore possible that the observed relationships between WTA, WTP and CE are due to some other mechanism. Indeed, any factor that causes CE to vary independently of WTA and WTP could potentially produce the effect shown in Figures 1 and 2. Second, and related, if one wished to maintain the theory that the disparities between these valuations are primarily due loss aversion, it might be argued that the effects evident above reflect some kind of separate, "second-order" phenomenon. Combining the two arguments, although we have explicitly hypothesised, tested and confirmed a novel and initially counterintuitive pattern in data from the original KKT design, it remains logically possible that the WTA-WTP disparity is primarily down to loss aversion, but that some (for now unspecified) additional factor influences the distribution of CE independently of WTA and WTP (or vice-versa).

This argument becomes weak, however, if the effect size of the empirical regularity we have revealed turns out to be relatively large. That is, if the movement in the value of CE relative to WTA and WTP is comparable in size with the WTA-WTP disparity itself, it is stretching credibility to argue that the effect has some unrelated and unspecified cause. To test this, we seek a more fine-grained analysis, which requires a method for pooling observations across experiments. Straightforward standardisation via the mean and standard deviation of valuations is hampered by the observations at maximum valuations. Instead, we match up realisations of order statistics to calculate observation-by-observation estimates of the relevant ratios.

The following describes the method for the WTA-CE comparison. The WTA and CE observations are separately ordered, then the order statistics are rescaled to fit the interval [0, 100]. The realisation of each order statistic is then matched with its corresponding realisation(s) in the larger sample.[12] This matching procedure produces an estimate of WTA/CE for each valuation in the smaller sample. We exclude valuations at the maximum, at zero, and also at the lowest available price, which is smaller than the price interval and hence makes the possible matches too coarse. We then pool the data across the experiments to generate 312 separate estimates of WTA/CE. The equivalent procedure for WTP produces 153 separate estimates of CE/WTP.

Figure 3 shows the results for WTA/CE. The fitted curve employed in the left panel to summarise the relationship is a cubic spline. The right panel shows mean WTA/CE by quintile. The decline in WTA/CE with CE is substantial and occurs steadily across the distribution. Figure 4 provides the equivalent analysis for CE/WTP. Since the sample is smaller and a greater proportion of WTP valuations occur at low prices where matches are more coarse, the data are somewhat noisier. Nevertheless, the increase in CE/WTP with CE remains clear.

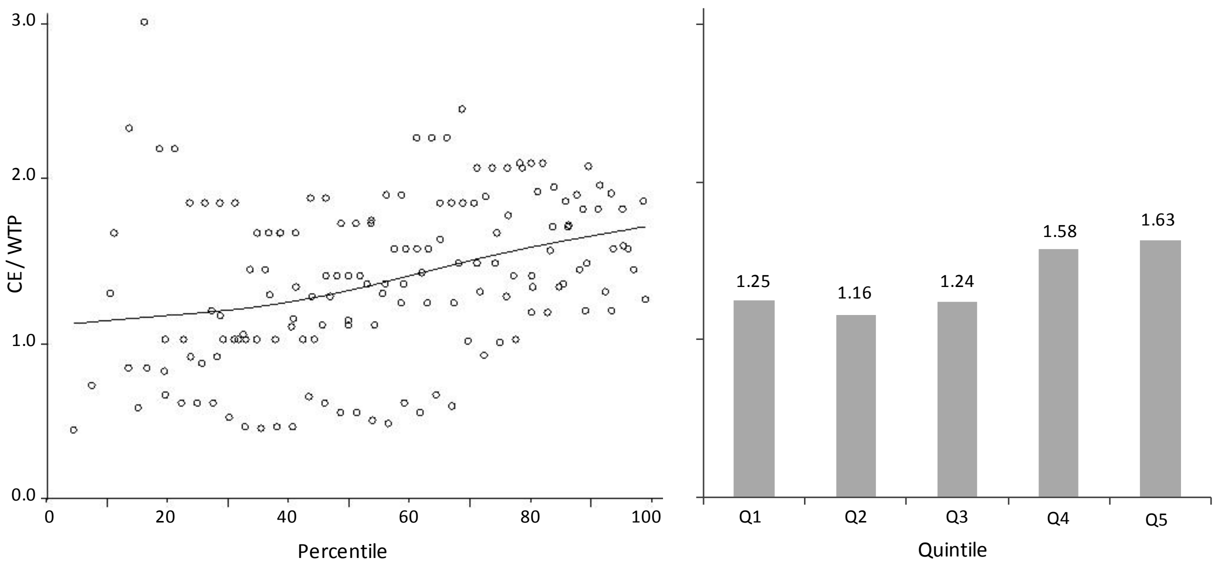
Figure 3: Variation in WTA/CE across the valuation distribution with pooled data. Individual observations (left) and mean WTA/CE by quintile (right).



[12] In six of the nine paired sets, there is a small difference in sample size, such that observations do not have a precise match, but correspond to a location between two realisations of order statistics in the other sample. For the results reported, we match observations in the smaller sample to a linear weighted average of adjacent realizations in the larger sample. Note that while this interpolation improves precision, the results are not sensitive to it: the outcome is almost identical if observations are matched instead to the nearest realisation.

This more fine-grained analysis provides estimates of the magnitude of the effects we reveal. By any measure, the effect size is large. Sellers in the bottom quintile of the valuation distribution require a proportional margin [(WTA – CE)/CE] that is more than three times greater than that required by sellers in the top quintile. Meanwhile, buyers in the top quintile require between two and four times as much surplus [(CE – WTP)/CE] as buyers in the lower two quintiles. The estimated ratios in which CE divides the WTP-WTA interval by quintile are: 17:83 (Q1), 16:84 (Q2), 25:75 (Q3), 50:50 (Q4), 61:39 (Q5). Across the distribution, the location of the CE valuation therefore differs by approximately half of the WTA-WTP gap itself. Moreover, recall that these estimates are likely to somewhat under-record the true extent of this variation, since the matching of the between-subject data tends to dampen the estimated effects (Appendix C). Thus, the magnitude of this variation across the valuation distribution is too large to be considered a peripheral or second-order phenomenon and needs instead to be explained by models of exchange.

Figure 4: Variation in CE/WTP across the valuation distribution with pooled data. Individual observations (left) and mean CE/WTP by quintile (right).



Contrary to transaction utility models, CE is estimated to be less than WTP in all quintiles. The pattern in the data is also difficult to square with the notion that the relativities between WTA, WTP and CE reflect the extent loss aversion for money. If the location of CE relative to WTA and WTP is considered to be a reflection of the relative loss aversion for items and for money (Bateman et al., 2005), then the data suggest that those who value an item most relative to others experience the least loss aversion for it, so much so that the degree of loss aversion is less than they experience when giving up money. This seems implausible.

6. Discussion

The CTE model makes novel and unique empirical predictions about the relationships between three valuations elicited in the original KKT experimental design: WTA, WTP and CE. Analysis of data gathered from multiple studies using the KKT design supports the predictions. Sellers with low valuations set WTA proportionally higher with respect to CE than those with high valuations, while buyers with high valuations set WTP proportionally lower with respect to CE than those with low valuations. The estimated magnitude of these effects is large relative to the WTA-WTP disparity itself.

These empirical effects are, admittedly, an indirect prediction of the CTE model, not a direct test of its main mechanism. So while the prediction and confirmation of these novel hypotheses provides initial support to the theory, there could in principle be an alternative explanation for the empirical pattern revealed. Prevailing theories of what lies behind the WTA-WTP disparity, however, do not appear to provide one. Consequently, the contribution of the present analysis goes beyond offering a test of the CTE model. At least as importantly, it demonstrates that other current theories are at odds with a consistent pattern in data gathered via the classic experimental design for demonstrating the phenomenon in question. Thus, the empirical findings reported here demand explanation.

With respect to reference dependent models, to be consistent with our findings, loss aversion would have to be greater for those who value a good least relative to other market participants, at least relative to loss aversion for money. These propositions do not follow from the original application of loss aversion to consumer choice (Tversky and Kahneman 1991), or from Köszegi and Rabin's (2006) proposal that reference states are defined by expectations, or from the theory that loss aversion places additional weight on the subset of loss-making outcomes when preferences are imprecise (Loomes et al., 2009). It may be possible to adapt models of the WTA-WTP disparity based on loss aversion to cope with the observed variation in the WTA-WTP-CE relationship, though it is not immediately obvious how. We note that there are, of course, separate bodies of evidence for loss aversion in various other decision-making contexts (Rick 2012).

What about other models of the WTA-WTP disparity? While it might be possible to derive the relationship between WTA and CE from an augmented version of Kling et al.'s (2013) dynamic model, adding assumptions about how option values scale with expected value, the model is at odds with the systematic variation we reveal between WTP and CE. Similarly, while models based on transaction utility (Isoni, 2010; Weaver and Frederick, 2012) can accommodate the pattern of variation in WTA and CE, they predict that CE will be less than WTP, provided WTP is lower than market or expected prices, as mostly it is. The data do not support this prediction.

Despite this latter shortcoming of transaction utility models, the present findings are arguably more easily accommodated by models of this sort where, in common with the CTE model, the WTA-WTP disparity results from the process of exchange rather than from the shape of preferences. This is so because the primary implication of the findings reported here is that when deciding WTA and WTP subjects consider how their valuation of the item compares to the valuations of other people.

References

Bardsley, N., Cubitt, R., Loomes, G., Moffatt, P., Starmer, C. and Sugden, R. (2010). Experimental Economics: Rethinking the Rules. Princeton, NJ: Princeton University Press.

Bateman, I., Kahneman, D., Munro, A., Starmer, C. and Sugden, R. (2005). Testing Competing Models of Loss Aversion: An Adversarial Collaboration. Journal of Public Economics, vol. 89, pp. 1561-80.

Baye, M.R., Morgan, J. and Scholten, P. (2006). 'Information, Search and Price Dispersion', in (Henderschott, T., ed.), Handbook on Economics and Information Systems, pp. 326-76, Amsterdam: Elsevier.

Brown, T. (2005). Loss aversion without the endowment effect, and other explanations for the WTA-WTP disparity. Journal of Economic Behavior & Organization, 57, 367-379.

Engelmann, D., & Hollard, G. (2010). Reconsidering the effect of market experience on the endowment effect. Econometrica, 78, 2005-2019.

Ericson, K.M. and Fuster, A. (2013). The endowment effect. NBER Working Paper No. 19384.

Franciosi, R., Kujal, P., Michelitsch, R., Smith, V. and Deng, G. (1996). 'Experimental tests of the endowment effect', Journal of Economic Behaviour and Organization, vol. 30, pp. 213-26.

Heffetz, O. and List, J.A. (2013). Is the endowment effect an expectations effect? Forthcoming in Journal of the European Economic Association.

Isoni, A. (2011). The willingness-to-accept/willingness-to-pay disparity in repeated markets: loss aversion or 'bad-deal' aversion? Theory and Decision, 71, 409-430.

Isoni, A., Loomes, G. and Sugden, R. (2011). The Willingness to Pay-Willingness to Accept Gap, the "Endowment Effect", Subject Misconceptions, and Experimental Procedures for Eliciting Valuations: A Reassessment. American Economic Review.

Kahneman, D. and Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. Econometrica, vol. 47, pp. 263-291.

Kahneman, D., Knetsch, J.L. and Thaler, R.H. (1990). 'Experimental Tests of the Endowment Effect and the Coase Theorem', Journal of Political Economy, vol. 98, pp. 1325-48.

Kling, C.L., List, J.A. and Zhao, J. (2010). A Dynamic Explanation of the Willingness to Pay and Willingness to Accept Disparity. NBER Working Paper No. 16483.

Knetsch, J.L (1989). 'The Endowment Effect and Evidence of Nonreversible Indifference Curves', American Economic Review, vol. 79, pp. 1277-84.

Köszegi, B. and Rabin, M. (2006). 'A model of reference-dependent preferences', Quarterly Journal of Economics, vol. 121, pp. 1133-66.

List, J.A. (2003). 'Does Market Experience Eliminate Market Anomalies?', Quarterly Journal of Economics, vol. 118, pp. 41-71.

List, J.A. (2006). Using Hicksian surplus measures to examine consistency of individual preferences: evidence from a field experiment. Scandinavian Journal of Economics, 108, 115-134.

Loomes, G., Orr, S. and Sugden, R. (2009). Taste uncertainty and status quo effects in consumer choice, Journal of Risk and Uncertainty, vol. 39, pp. 113-35.

Lunn, P.D. and Lunn M. (2014). A computational theory of willingness to exchange. ESRI Working Paper 477.

Marr, D. (1982). Vision: A computational investigation into the human representation and processing of visual information. New York: W.H. Freeman.

Mazar, N., Köszegi, B. and Ariely, D. (2010). Price-Sensitive Preferences. Working Paper, University of Califormia.

Novemsky, N. and Kahneman, D. (2005). The Boundaries of Loss Aversion. Journal of Marketing Research, vol. 42, pp. 119-28.

OECD (2006). Cost-Benefit Analysis and the Environment: Recent Developments. Paris: OECD.

Plott, C.R. and Zeiler, K. (2005). 'The Willingness to Pay-Willingness to Accept Gap, the "Endowment Effect," Subject Misconceptions, and Experimental Procedures for Eliciting Valuations', American Economic Review, vol. 95, pp. 530-45.

Plott, C.R. and Zeiler, K. (2011). The willingness to pay-willingness to accept gap, the "endowment effect," subject misconceptions, and experimental procedures for eliciting valuations: reply. American Economic Review, 101, 1012-1028.

Rick, S.I. (in press), "Losses, Gains, and Brains: Neuroeconomics Can Help to Answer Open Questions about Loss Aversion," Journal of Consumer Psychology.

Ross, L., Green, D. and House, P. (1977). The "False Consensus Effect": An Egocentric Bias in Social Perception and Attribution Processes Journal of Experimental Social Psychology, vol. 13, pp. 279-301.

Shogren, J.F., Shin, S.Y., Hayes, D.J. and Kliebenstein, J.B. (1994). 'Resolving Differences in Willingness to Pay and Willingness to Accept', American Economic Review, vol. 84, pp. 255-70.

Tversky, A. and Kahneman, D. (1991). 'Loss Aversion in Riskless Choice: A Reference-Dependent Model', The Quarterly Journal of Economics, vol. 106, pp. 1039-61.

Van Boven, L., Dunning, D. and Loewenstein, G. (2000). Egocentric Empathy Gaps Between Owners and Buyers: Misperceptions of the Endowment Effect. Journal of Personality and Social Psychology, vol. 79, pp. 66-76.

Weaver, R. and Frederick, S. (2012). A reference price theory of the endowment effect. Journal of Marketing Research, 49, 696-707.

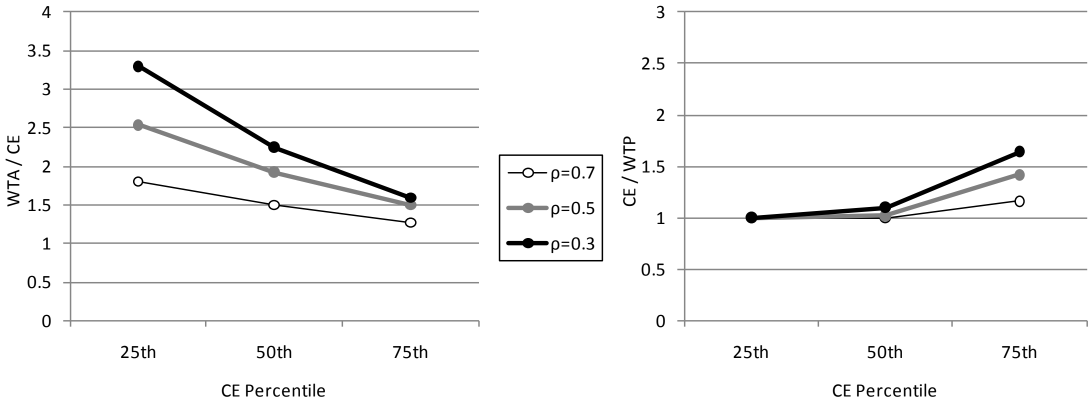
Appendix A: Simulations to Assess the Impact of Correlation Between Private Values and perceptions of Bids and Offers

Empirically, all three valuation distributions (WTP, CE, WTA) are approximately log-normal, once the tendency for valuations to be drawn to prominent round numbers is discounted. We therefore assume that private values, x_i, are distributed as $\log X \sim N(\mu_1, \sigma_1)$ and that (in the case of setting WTA) agents perceive bids distributed as $\log Y \sim N(\mu_2, \sigma_2)$. Correlation between X and Y is introduced by setting $P_1 = (X - \mu_1)/\sigma_1$ and $P_2 = (Y - \mu_2)/\sigma_2$, where P_1 and P_2 have a joint bivariate normal distribution with $\text{corr}(P_1, P_2) = \rho$. We then use the CTE model (Equation 2, Section 3.1 of main text) to simulate the setting of WTA for a range of x_i and any combination of μ_1, σ_1, μ_2, σ_2, c and ρ. (The set-up for WTP is identical, with Y substituted by Z and the solution supplied by Equation 4).

To explore the effects of individual-level correlation between private values and perceptions of bids (offers), we set μ_1, σ_1, μ_2 and σ_2 to match the parameters of the empirically observed valuation distributions. Thus, the distribution of private values (X) is parameterised using the observed CE valuations. For sellers, the perceived distribution of bids (Y) is parameterised using observed WTP valuations, but with the distribution biased by own valuation as determined by ρ. Similarly, buyers perceive offers (Z) that match the observed WTA distribution with a bias dictated by ρ.

Given this set-up, we explore how WTA/CE and CE/WTP vary with CE for different values of c and ρ. Figure A1 displays typical output. The valuation distributions in this case are parameterised according to the observed valuations of NK Exp 8, which is in effect the median experiment with respect to the extent of disparity between valuations (Table 1, Section 5 or main text). The item is a bag of Godiva chocolates with mean CE of $6.24. Figure A1 is based on an encounter cost, c, of $0.20. Results are given for agents with CE valuations at the 25th, 50th and 75th percentile and three values of ρ (0.3, 0.5, 0.7).

Figure A1: Example of simulated WTA/CE (left) and CE/WTP (right) against CE for various degrees of correlation between private values, x_i, and perceptions of bids (Y) and offers (Z) respectively.



As anticipated, individual-level correlation between private values and perceptions of others' valuations weakens the predicted relationship. The gradients are also reduced by higher encounter costs. Our general finding from this simulation exercise, however, is that if perceptions approximate observed valuation distributions, both predictions continue to hold for realistic encounter costs and extents of perceptual bias. To extinguish the gradients apparent in Figure A1 requires an encounter cost greater than 10% of mean CE and an extremely strong bias towards own valuation, e.g. ρ = 0.8-0.9, or even greater in the case of WTA/CE. We conclude that the two predictions are robust to this potential bias in perceptions of bids and offers.

Appendix B: Prediction of Loomes et al. (2009)

From Loomes et al., bundle x is weakly preferred to bundle y at reference bundle z if $v(x,z) \geq v(y,z)$ where $v(x,z) = \sum_h \pi(s_h)\varphi(u_h(x) - u_h(z))$; final consumption occurs in a "taste state", s_h (h = 1, ..., m), with probability $\pi(s_h)$; $u_h(.)$ is the utility function for state h; and $\phi(.)$ is a real valued function such that $\phi(0) = 0$, $\phi'(0^+) = 1$ and $\phi'(0^-) = \beta$, $\beta > 1$, i.e. individuals are loss averse in utility. Still following the original, we consider goods 1 and 2 with marginal utilities $U_h = \partial u_h(z)/\partial x_1$ and $V_h = \partial u_h(z)/\partial x_2$. We then depart from the original by not including the normalisation $\sum_h \pi(s_h)U_h = \sum_h \pi(s_h)V_h = 1$, which effectively sets CE = 1. Instead, note that δz_1 is an increase in good 1 equivalent to an increase δz_2 in good 2 if

$$\sum_h \pi(s_h)\varphi(u_h((z_1 + \delta z_1, z_2)) - u_h(z)) = \sum_h \pi(s_h)\varphi(u_h((z_1, z_2 + \delta z_2)) - u_h(z)) \tag{B1}$$

and (taking first derivatives)

$$\varphi'(0^+)\sum_h \pi(s_h)U_h\delta z_1 = \varphi'(0^+)\sum_h \pi(s_h)V_h\delta z_2 , \tag{B2}$$

defining CE = $\delta z_2/\ \delta z_1$. Next, we assume that good 1 is the consumer item and good 2 is money. We define our ratio of interest r_{21} = WTA/CE. Thus, the agent should be indifferent between the reference state and selling good 1 at WTA, or

$$\sum_h \pi(s_h)\varphi(u_h((z_1 - \delta z_1, z_2 + r_{21}\delta z_2)) - u_h(z)) = 0 \ . \tag{B3}$$

To differentiate we need to know the sign of the argument of $\phi(.)$. Again following the original, we order taste states $U_1/V_1 \geq U_2/V_2 \geq \dots U_m/V_m$, and define $\{s_1, \dots s_K\}$ states in which the argument is negative and $\{s_{K+1}, \dots s_m\}$ in which it is positive. Differentiating,

$$\beta\sum_1^K \pi(s_h)(-\delta z_1U_h + r_{21}\delta z_2V_h) + \sum_{K+1}^m \pi(s_h)(-\delta z_1U_h + r_{21}\delta z_2V_h) = 0 , \tag{B4}$$

which gives

$$r_{21} = \frac{\delta z_1}{\delta z_2}\left(\frac{\beta\sum_1^K \pi(s_h)U_h + \sum_{K+1}^m \pi(s_h)U_h}{\beta\sum_1^K \pi(s_h)V_h + \sum_{K+1}^m \pi(s_h)V_h}\right). \tag{B5}$$

We now consider an increase in CE caused by a proportionate increase in the marginal utility of good 1 across taste states, i.e.

$$\delta z_1\sum_1^m \pi(s_h)U_h = \delta z_2\sum_1^m \pi(s_h)V_h = \delta z_1'\sum_1^m \pi(s_h)U'_h , \tag{B6}$$

where $\delta z_1' < \delta z_1$ and $U'_h = (\delta z_1 / \delta z_1')U_h = \lambda U_h, \lambda > 1$. The agent will be willing to sell at the same r_{21}, i.e. at the same WTA/CE, if and only if v'(x, z) ≥ v(x, z). To determine this we derive

$$v'(x,z) - v(x,z) = \beta \sum_{1}^{L} \pi(s_h)(-\delta z_1 \lambda U_h + r_{21}\delta z_2 V_h) + \sum_{L+1}^{m} \pi(s_h)(-\delta z_1 \lambda U_h + r_{21}\delta z_2 V_h) - \beta \sum_{1}^{K} \pi(s_h)(-\delta z_1 U_h + r_{21}\delta z_2 V_h) - \sum_{K+1}^{m} \pi(s_h)(-\delta z_1 U_h + r_{21}\delta z_2 V_h)$$

$$= \beta \sum_{1}^{K} \pi(s_h)(-\delta z_1 \lambda U_h + \delta z_1 U_h) + \beta \sum_{K+1}^{L} \pi(s_h)(-\delta z_1 \lambda U_h + r_{21}\delta z_2 V_h) - \sum_{K+1}^{L} \pi(s_h)(-\delta z_1 U_h + r_{21}\delta z_2 V_h) - \sum_{L+1}^{m} \pi(s_h)(-\delta z_1 U_h + \delta z_1 \lambda U_h) \quad \text{(B7)}$$

where $L \geq K$ because $U'_h > U_h$. Each of the four terms on the right in Equation B7 is negative, the first and fourth because λ > 1, the second and third because h > K. Hence, the agent will not sell at the previous WTA/CE and must increase WTA/CE at the higher CE. This result holds provided the increase in U_h is order preserving in U_h/V_h. In other words, WTA/CE is increasing in CE provided there is no additional relationship proposed between CE and the set of possible taste states.

Appendix C: Implications of the order-preserving assumption for analysis of between-subjects experimental data

We consider the case of between-subjects data for WTA (W) and CE (C), sorted into order. The upper of two quantiles is given the subscript u, the lower quantile the subscript l.

The CTE model predicts:

$$\frac{W_u}{C_u} < \frac{W_l}{C_l} \tag{C1}$$

Or equivalently:

$$\frac{w_{2k} + \cdots + w_{k+1}}{C_u} < \frac{w_k + \cdots + w_1}{C_l} \tag{C2}$$

where $w_i < w_j$ for i < j. Consider a permutation in which we leave the denominator the same but permute the numerator:

$$II = -\frac{w_{\pi(2k)} + \cdots + w_{\pi(k+1)}}{C_u} + \frac{w_{\pi(k)} + \cdots + w_{\pi(1)}}{C_l} \tag{C3}$$

and suppose that:

$$I = -\frac{w_{2k} + \cdots + w_{k+1}}{C_u} + \frac{w_k + \cdots + w_1}{C_l} > 0 \tag{C4}$$

Now *I* is the statistic we have measured in the between-subjects experiment and *II* is the statistic that would be produced by an equivalent within-subjects experiment in which order was not preserved.

Consider *II – I*. If w_i is in the same (upper or lower) set using π then there is no change. If, instead, we switch w_j from the lower quantile to the upper one and w_{k+i} from upper to lower under π then:

$$II - I = \frac{w_{k+i}}{C_l} - \frac{w_j}{C_u} - \frac{w_j}{C_l} + \frac{w_{k+i}}{C_u} > 0 \qquad \text{(C5)}$$

Thus, we are more likely to get a positive answer if the assumption of order-preservation is violated than if we compute the test statistic by matching quantiles with between-subject data.

Note that the equivalent conclusion for CE/WTP holds by similar argument, since CE/WTP increasing in CE also implies equation (1) above.

Year	Number	Title/Author(s) ESRI Authors/Co-authors *Italicised*
2014		
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	477	A Computational Theory of Willingness to Exchange *Pete Lunn* and Mary Lunn
	476	Who Feels Inferior? A Test of the Status Anxiety Hypothesis of Social Inequalities in Health *Richard Layte* and Christopher T. Whelan
2013		
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