# Real Options and the WTP/WTA Disparity

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**Abstract**

We present a real options model of an agent's decision to purchase or sell a good under conditions of uncertainty, irreversibility, and learning over time. Her WTP and WTA contain both the intrinsic value of the good and an option value associated with delaying the decision until more information is available. Consequently, the standard Hicksian equivalence between WTP/WTA and compensating and equivalent variation no longer holds. This helps to explain the WTP/WTA disparity often observed in laboratory experiments and surveys because subjects may have limited learning time and opportunities, thus generating option values. In contrast, the disparity may decrease or disappear entirely in real markets since agents are free to choose when to stop gathering information, thereby reducing or eliminating the option values. We also discuss experimental evidence that supports the option value hypothesis. (*JEL*: D60, D83, C90)

Hicksian welfare theory forms the basis of modern welfare analysis. This theory is static and therefore the relationship between standard welfare measures such as willingness to pay (WTP) or willingness to accept (WTA) and the passage of time has not received much attention. However, in many market decisions where it takes time to gather information, timing of the transaction is an integral part of the decision. For example, an art collector considering selling a painting may want to gather information about the painting's market value before deciding to offer it for sale. Likewise, a consumer considering the purchase of a new style of blue jeans might want to learn more about current styles and substitutes before actually making the purchase, especially if the store has a limited return policy. Thus, timing may play a key role in market transactions by allowing agents to acquire information about the good, such as the prevailing market prices (including substitutes), and to solidify their own preferences for the good.

Consequently, the time at which WTP or WTA is formed may affect their magnitude. If there are nontrivial transaction costs associated with reversing the decision and the agent has some uncertainty about the value of the good, she may prefer to delay the decision in order to obtain additional information about the good's value. This information helps the agent to reduce the likelihood of having to reverse her trade (thus incurring the associated transaction cost) later on. As Arrow and Fisher (1974), Henry (1974), Epstein (1980) and Dixit and Pindyck (1994) have demonstrated, this role of future information means that there is a benefit, called quasi-option value (QOV),[1] associated with waiting to make a decision. Thus, to make a purchase on the first day that the new styles are in the stores, the jeans shopper will be willing to pay less than she might if she waited and gathered further information. Alternatively, for the art collector to sell the painting to the first bidder and forego further learning, she will demand a higher price in

[1]QOV is distinct from the option value concept introduced by Weisbrod (1964). The Weisbrod option value is fundamentally a risk aversion premium. Quasi-option value, on the other hand, measures a conditional value of information and exists even for risk neutral agents. See Hanemann (1989) for additional discussion of QOV.

compensation for the quick action. In both cases, the price at which the buyer or seller is willing to purchase or sell the good (WTP or WTA) is determined both by the intrinsic value of the good and how quickly the decision has to made (or the amount of information available).

In this paper, we present a model that explicitly demonstrates the effect that timing of an action can have on welfare measurement. Specifically, if the agent is forced to abandon her learning opportunities and make a quick decision, her WTP for a commodity will be reduced by an option value, and her WTA will be increased by another option value. Readers familiar with the real options literature in investment theory will recognize that these concepts are analogous to option values arising in investment decisions. Since option values, in addition to the intrinsic value of the good (i.e., compensating or equivalent variation), enter the WTP/WTA measurement, the standard relationship in Hicksian welfare theory between the WTP and WTA and equivalent and compensating variations fails to hold if one or both option values arise.

These option values generally decline in magnitude as the agent has more time to gather information before making the decision. They may disappear if eventually the agent finds further information gathering not worthwhile (i.e. the option of further waiting becomes worthless) and *voluntarily* stops waiting and makes the transaction. Therefore, the WTP and WTA values are time dependent (or more accurately, information dependent). WTP and WTA may accurately measure EV or CV if the agent chooses the time of the transaction; however, if the agent is forced to make a purchase or sale decision, her WTP/WTA may differ from CV or EV by the size of the option values.

These observations have far reaching implications for theoretical and empirical studies of welfare measurement. For example, they provide an explanation for the often observed divergence between reported WTP and WTA values in lab experiments and contingent valuation surveys.[2] We show

[2]See Harbaugh, Krause and Vesterlund (1998) for a nice review of the experimental evidence on these divergences.

that these "anomalies" can arise when experiments and surveys restrict the time and opportunity a subject has to gather relevant information. Then the WTP/WTA disparity is the logical consequence of irreversibility (or adjustment costs), uncertainty and timing of the transaction.

Further, the possible existence of option values raises doubt as to the validity of routinely using WTP/WTA as measures of the Hicksian compensating and equivalent variations, particularly in nonmarket valuation settings. Our theory suggests modifications in experiment and survey design that would reduce or eliminate the option values if CV/EV is the value of interest.

The paper is organized as follows. Section 1 constructs a model of an agent's decision to buy or sell a good, under conditions of uncertainty and irreversibility. WTP and WTA are seen to contain option values and variables that affect the magnitude of these option values are examined. We also examine the relationship between WTP/WTA and the Hicksian concepts of compensating and equivalent variation. In Section 2, we investigate the implications of our model for the WTP/WTA disparity found in laboratory experiments and contingent valuation surveys. We show how option values can provide a coherent explanation for the divergence and we examine the pre-existing evidence to provide support for this contention. In Section 3, we discuss our model's predictions for WTP/WTA divergences in competitive markets and its implications for welfare analysis.

## 1 A Model of WTP/WTA Formation

In this section, we model an agent's decision to purchase or sell a good when the good has uncertain value to the agent. We assume that information becomes available over time and thereby reduces this uncertainty. To isolate the role of option values, we consider only two goods, a composite good (or money) and the specific good being traded, with perfect substitution between them. In particular, the agent's utility function is given by

$$U(m,n) = m + Gn, \tag{1}$$

where $m$ is money, $n$ is the amount of the traded good, and $G$ is its unit value. This utility function implies that the agent is risk neutral, with constant elasticity of substitution between the two goods.

For simplicity, the agent can only trade *one unit* of the specific good. Suppose the agent can trade in either period one (current) or two (future). She is uncertain about the value $G$, and her current belief is described by distribution $F_0(\cdot)$, or density function $f_0(\cdot)$, both defined on $[0, G_H]$.[3] She knows that more information about $G$ will be available in period two, and specifically, the information comes in the form of a *signal* about $G$, denoted by $s \in S \subset \mathcal{R}$, where $S$ is the set of all possible signals. There is no cost associated with acquiring the signal. However, the agent must wait until period two to obtain the information. Conditional on the true value of $G$, the possible signals are described by the conditional density function $h_{s|G}(\cdot)$, defined on $S$. Let $h(\cdot)$ be the unconditional density function of signal $s$, i.e., $h(s) = \int_0^{G_H} h_{s|G}(s)dF_0(G)$, and let $H(\cdot)$ be the corresponding distribution function. Observing $s$, the agent updates her belief about $G$ according to the Bayesian rule, $f_{G|s}(G) = h_{s|G}(s)f_0(G)/h(s)$. The associated conditional distribution function is denoted as $F_{G|s}(\cdot)$.

To fix ideas, suppose an agent is considering purchasing a particular painting. She has some idea (described by her prior $F_0$) about its value to her, but before making an offer, she wishes to consult her friend who is an art dealer. Her dealer friend agrees, but can only inspect the painting two weeks later. In this example, the signal is her friend's opinion that she will rely on to update her own belief about the painting's value. Thus, our potential art patron can either make an offer now with her current level of knowledge and associated uncertainty, or wait for two weeks when

[3] Without loss of generality, we let the lowest possible value of $G$ to be zero. We could use a more general representation, such as $G_L$ $(< G_H)$, without affecting the results of our model.

she can make an offer based on a better estimate of the painting's value.

For simplicity, we assume that the agent observes the true value of $G$ *immediately* after she finishes the trade.[4] After $G$ is realized, the agent can reverse the trade, that is, return the good that she purchased or buy back the good that she sold, at a certain cost. Let $c_P > 0$ denote the cost of returning and $c_A > 0$ the cost of re-purchasing the good. *Ex post*, it may be desirable to return the good and incur $c_P$ if $G$ turns out to be quite low, and re-purchase the good and incur $c_A$ if $G$ is quite high. In our example, if the art patron purchases the painting, but later finds it less appealing, she may wish to resell it. However, this may involve significant transaction costs if the secondary market is not well established, say if she has to auction the painting off on her own.

Another factor is that the agent may be anxious to use the good or the proceeds from selling the good and is therefore less willing to wait for the signal. To capture this *impatience*, we assume that she discounts the second period benefit at rate $\beta \in [0, 1]$. Note that $\beta$ may equal 1 (no discounting) if the agent currently does not need the good or the proceeds from selling it. Again in our example, the art patron may be very impatient (i.e. have a low $\beta$) if say she needs the painting for a party the next day. But her $\beta$ would be much higher if the painting is needed for a party next month. In the latter case, she will be more likely to wait for her dealer friend's opinion before making an offer.

In traditional static welfare measurement where the option of future learning is not considered, WTP is defined to be the maximum price the agent is willing to pay for the good, and WTA is the minimum price she requires for giving up the good. We denote these concepts as $WTP_S$ and $WTA_S$ respectively. However, when the possibility of future learning is considered, we have instead that:

[4] Usually a buyer learns the true value of a good after using it, implying that she observes $G$ after purchasing the good. Similarly, a seller often learns the true market value of a good after other people have bought, used, and possibly re-sold it. We assume away the time lag between trading and the realization of $G$, without affecting the major results of our model.

**Definition 1** *$WTP$ is the maximum price at which an agent is willing to buy the good* ***in the current period****, and $WTA$ is the minimum price at which she is willing to sell the good* ***in the current period****.*

To determine $WTP$ and $WTA$, we set an arbitrary price $p$ for the good and consider whether the agent would want to trade now or wait for the signal. Intuition suggests that if the price is sufficiently low, the agent will want to buy now since the signal will not be very useful. Similarly, she will sell now if the price is sufficiently high. Indeed, we will show that there exists a critical price, $p_P$, at which she is indifferent between buying now and waiting (i.e. below which she would buy now and above which she would want to wait), and a critical price, $p_A$, at which she is indifferent between selling now and waiting (i.e. below which she would want to wait and above which she would sell now). Then $WTP = p_P$ and $WTA = p_A$.

### 1.1 The determination of $WTP$

Define $V(p,s)$ to be the expected net surplus of the agent if she purchases one unit of the good at price $p$ after observing signal $s$. That is,

$$\begin{aligned} V(p,s) &= \int_0^{G_H} \max\{p - c_P, G\} dF_{G|s}(G) - p \\ &= \int_0^{G_H} \max\{-c_P, G - p\} dF_{G|s}(G). \end{aligned} \tag{2}$$

The integrand, $\max\{p - c_P, G\}$, represents the agent's *ex post* decision to keep the good (thus getting $G$) or return it (thus getting her money $p$ back, minus the transaction cost, $c_P$). To reduce clutter, we let $V(p,0)$ be the expected net surplus based on the prior information $F_0$ (i.e. without observing any signals).[5] That is, $V(p,0) = \int_0^{G_H} \max\{-c_P, G-p\} dF_0(G)$.

Since $\max(\cdot)$ is a convex operator, we know $V(p,s)$ is decreasing and convex in $p$. If $p \leq c_P$,

[5]To make this statement strictly true, we have to require that $0 \in S$, and signal 0 does not contain any information about $G$.

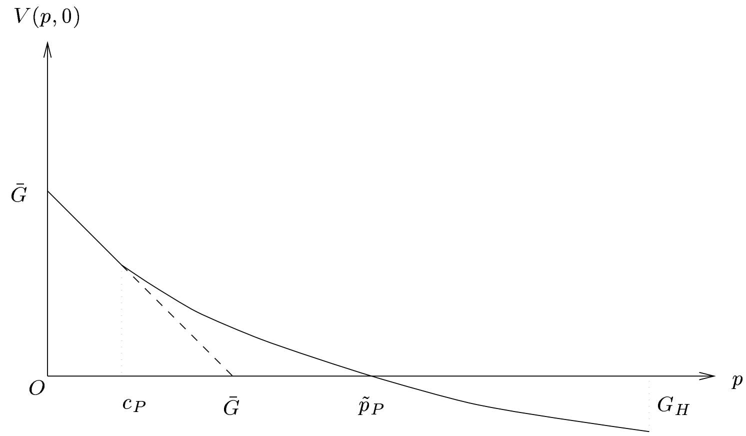



Figure 1: Static Welfare Measurement: $WTP$

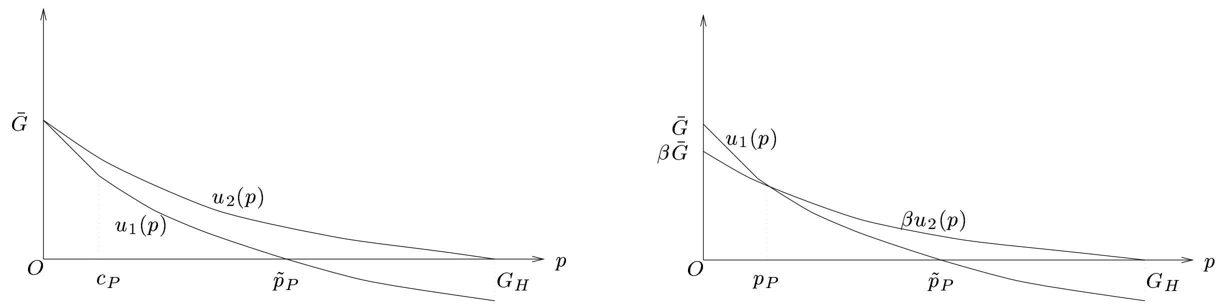
$\max\{-c_P, G-p\} = G-p$ for all $G \in [0, G_H]$ (i.e., the agent will never return the good). In this case $V(p,s) = \bar{G}(s) - p$ where $\bar{G}(s) = \int_0^{G_H} GdF_{G|s}(G)$ is the expected value of $G$ if signal $s$ is observed. If $p = G_H$, $\max\{-c_P, G-p\} \leq 0$ for all $G \in [0, G_H]$. Continuity of $V(p,s)$ in $p$ then implies that $V(p,s) < 0$ for $p$ sufficiently close to $G_H$. Figure 1 graphs $V(p,0)$, where $\bar{G}$ stands for $\bar{G}(0)$. Since $V(p,0) = 0$ at the unique $p = \tilde{p}_P$, we know $\tilde{p}_P$ is the static measure of the agent's WTP, or $WTP_S$. Note that $\tilde{p}_P > \bar{G}$, the expected value of the good, due to the existence of the return option.[6] It is obvious from Figure 1 that $\tilde{p}_P = \bar{G}$ if $c_P$ is sufficiently high. That is, the static $WTP_S$ equals the intrinsic value of the good $\bar{G}$ when returning the good becomes too costly. We consider this special case later in this section.

Let $u_1(p)$ be the agent's expected net surplus if she buys the good at price $p$ in period one. It is obvious that

$$u_1(p) = V(p,0) = \int_S V(p,s)dH(s). \tag{3}$$

Let $u_2(p)$ be her expected net surplus if at price $p$, she does not buy in period one, but instead makes her decision in period two. Observing $s$, the agent will buy the good only if her expected

[6]The difference $\tilde{p}_P - \bar{G}$ is the value of the "money-back guarantee" under which the agent can return the good at cost $c_P$. This value has been modeled in a greater detail in Heiman, Zhao and Zilberman (1998).




(a) $\beta = 1$ (b) $\beta < 1$

Figure 2: Dynamic Welfare Measurement: $WTP$

surplus conditional on $s$ is nonnegative, yielding expected payoff $\max\{0, V(p,s)\}$. Thus *ex ante*, before the signal is realized, her expected surplus of not buying in period one is

$$u_2(p) = \int_S \max\{0, V(p,s)\} dH(s) = \int_{S_{P1}(p)} V(p,s) dH(s), \tag{4}$$

where $S_{P1}(p) = \{s \in S : V(p,s) \geq 0\}$. Since $V(p,s)$ is decreasing and convex in $p$, so are $u_1(p)$ and $u_2(p)$. Comparing (3) and (4), we know $u_1(p) \leq u_2(p)$ for all $p \in [0, \bar{G}]$, and the inequality is strict if $S_{P1}(p)$ has a probability measure of less than one. Appendix A shows that this condition is satisfied if for any $p > 0$, there are always some signals that would predict that the good's value is very likely below $p$. We assume that this condition is true. The expression $u_2(p) - u_1(p)$ then measures the gain (without discounting) from waiting: new information enables the agent to avoid "bad" purchases for which the signal $s$ falls in the "no-purchase" set, $S_{P2}(p) = S \backslash S_{P1}(p) = \{s \in S : V(p,s) < 0\}$.

Figure 2(a) graphs both $u_1(p)$ and $u_2(p)$. Note that $u_2(0) = u_1(0) = \bar{G}$ since when $p = 0$, $V(0,s) \geq 0$ for all $s \in S$, or $S_{P1}(0) = S$. That is, when the price is zero, the agent will buy the product whose value is nonnegative regardless of the signal, so waiting becomes pointless. $u_2(G_H) = 0$ since if $p = G_H$, the expected net payoff $V(G_H, s)$ is negative regardless of the signal. Then, the agent will not buy the good for any realization of the signal, and the net benefit is zero.

In fact, Figure 2(a) illustrates the optimal decision when there is no discounting. Since $u_2(p) >$

$u_1(p)$ for $p > 0$, the agent always waits for the signal if $p > 0$. This result is obvious: since waiting incurs no cost but can prevent possible "bad purchases" (the case of $V(p, s) < 0$) when $p > 0$, she will not buy in the current period. Thus, the agent's $WTP$ in the current period is zero, the lowest possible value of $G$.

The effect of discounting is illustrated in Figure 2(b). The discount factor is $\beta < 1$, and the $WTP$ is $p_P$ at which $u_1(p_P) = \beta u_2(p_P)$. If the agent is asked to buy the good at a price $p$, and she has to answer *now*, then her answer will be "no" if $p > p_P$ and "yes" if $p \leq p_P$. Thus $WTP = p_P$. Appendix A shows that $p_P$ exists and is unique.

$WTP$ is closely related to the Arrow-Fisher-Henry quasi-option value given by $QOV(p) = \max\{0, \beta u_2(p) - u_1(p)\}$. For a given price $p$, quasi-option value measures the additional benefit of being able to wait for the new information, conditional on the fact that waiting occurs (Hanemann, 1989). Then the $WTP$ is the maximum price at which $QOV$ is zero:[7] in the current period, the agent will not pay a higher price than $p_P$, because at that price she will simply wait instead of making the purchase.

In this paper, we define a distinct concept of "option value" that measures the difference between the static and dynamic $WTP$: $OV_P = \tilde{p}_P - p_P \geq 0$, or written differently,

$$WTP = WTP_S - OV_P. \tag{5}$$

This option value is the compensation, in terms of a lower price (for both periods), that the agent demands to give up the option of waiting by buying the good now. It represents the minimum amount of money, in terms of an overall price reduction, needed to induce the agent to buy in this period. Conceptually, it is similar to $QOV(\tilde{p}_P)$: given price $\tilde{p}_P$, both option values measure how much is needed to induce the agent to buy in the current period. The difference is that $QOV$ is

[7]Strictly, $WTP = \inf\{p \in [0, G_H] : QOV(p) > 0\}$.

expressed in terms of a direct income transfer, while $OV_P$ is expressed in terms of a price cut for both periods.[8]

Consider again the painting example. Suppose the listed price of the painting is $\tilde{p}_P$. Without the option of her friend's help, the patron is indifferent between buying and not buying. However, given the possibility of information from her friend, she will wait at this price. The seller could induce her to buy *now* in one of two ways: either by offering the patron a *one-time discount* (equivalent to a direct income transfer) of at least $QOV(\tilde{p}_P)$, or by permanently lowering the price by at least $OV_P$. The permanently lower price may induce a current purchase because it lowers the value of the future information. The one-time discount is offered only if the agent buys now, so that she will have to pay $\tilde{p}_P$ if she buys two weeks later, while the price change lasts for at least two weeks. Thus, $QOV$ is measured in direct income transfer, while $OV_P$ is measured in (permanent) price discounts.

$WTP$ as well as the option value $OV_P$ depends on the incentive of the agent to wait for new information. Intuition suggests that this incentive rises as the agent becomes more patient, as future signal becomes more informative about the good, or as the cost of returning the good (or the penalty for making a bad purchase) increases. Proposition 1 (proved in Appendix A) shows that this intuition is correct, where the informativeness of the signal is defined in the sense of Blackwell (1951, 1953): $S'$ is more informative than $S$ if $h_{s'|G}$ is sufficient for $h_{s|G}$.

**Proposition 1** *$WTP$ is decreasing in $\beta$, the informativeness of signal $S$, and the return cost $c_P$. $OV_P$ is increasing in $\beta$ and the informativeness of $S$.*

[8] An alternative way to relate the two concepts is to note that $OV_P$ represents the flip side of $QOV$: given a certain price, $QOV$ represents the required compensation, through an income transfer, for the agent to buy now. $OV_P$ measures how much of a price discount is needed to induce the agent to buy now. Mathematically, the two option values are different.

**Special case: absolute irreversibility**

Now we consider the special case where $c_P \geq G_H$ so that the agent will never return the good and the purchase is absolutely irreversible. This case is interesting not only because it generates an analytical solution for $WTP$ and $OV_P$, but also because it represents interesting real world situations. For instance, destruction of an old growth forest or significant erosion of fragile coastline habitat are extremely costly to reverse. Additionally, and of particular relevance for the WTP/WTA divergence, return options are not available in most experimental economics settings or contingent valuation studies. The following results will bear directly on that discussion.

From (2), we know that with $c_P \geq G_H$, $V(p,s) = \int_0^{G_H} (G-p)dF_{G|s}(G) = \bar{G}(s) - p$. Thus $WTP_S = \bar{G}$. Appendix A shows that

$$OV_P = \frac{\text{Prob}(S_{P2})}{\frac{1}{\beta} - \text{Prob}(S_{P1})} \left[\bar{G} - E(G|S_{P2})\right], \qquad \text{and} \tag{6}$$

$$WTP = \bar{G} - OV_P = WTP_S - OV_P, \tag{7}$$

where $E(G|S_{P2}) = \frac{1}{\text{Prob}(S_{P2})} \int_{S_{P2}} \bar{G}(s)dH(s) < \bar{G}$ is the expected value of $G$ conditional on $s \in S_{P2}$ being realized. Note that $E(G|s) < \bar{G}$ for all $s \in S_{P2}$, since $S_{P2}$ is the set in which realized signals predict low $G$ values (thus no purchase is made). Thus $OV_P > 0$. Further, $OV_P$ increases in $\beta$, the size of the regret set, $S_{P2}$, which can be avoided by waiting, and the expected penalty for making a mistake, $\bar{G} - E(G|S_{P2})$.

## 1.2 The determination of $WTA$

The derivation of $WTA$, shown in Appendix A, is exactly parallel to that of $WTP$. $W(p,s)$, the net gain of selling one unit of the good at $p$ when the signal is $s$, is increasing and convex in $p$. Figure 3 graphs the expected net benefit of selling in the first period (i.e. without waiting for the signal), $W(p,0)$. $\tilde{p}_A$ is the minimum price the agent requires to give up the good, and is thus the

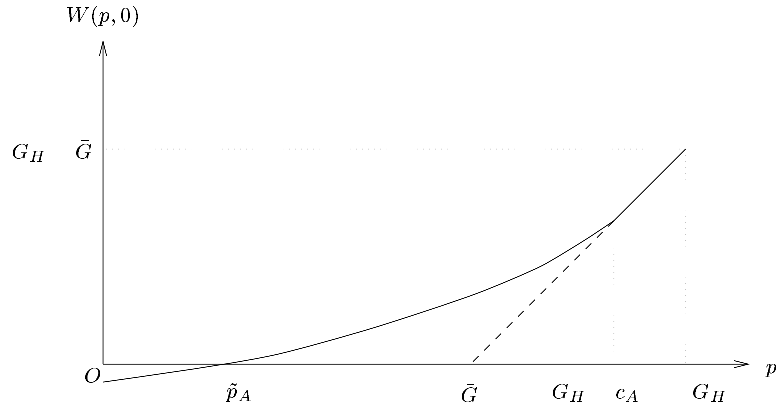



Figure 3: Static Welfare Measurement: $WTA$

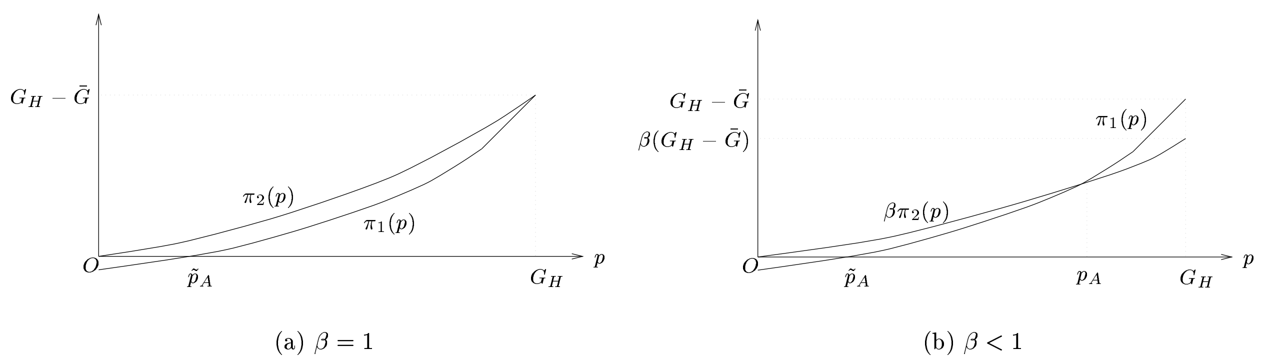



Figure 4: Dynamic Welfare Measurement: $WTA$

static $WTA$ measure, $WTA_S$. Again $\tilde{p}_A < \bar{G}$ due to the "goods-back guarantee:" since she can buy it back if the good turns out to be highly valuable, she is willing to sell the good at a lower price than she otherwise would.

Let $\pi_1(p)$ and $\pi_2(p)$ be the agent's expected net surplus if she decides to sell the good in period one and to wait one more period, respectively. Figure 4 graphs $\pi_1(p)$ and $\beta\pi_2(p)$ for both $\beta = 1$ and $\beta < 1$. Without discounting, $WTA = G_H$, and with discounting, $WTA = p_A > \tilde{p}_A = WTA_S$.

Defining $OV_A = p_A - \tilde{p}_A \geq 0$, we know

$$WTA = WTA_S + OV_A. \tag{8}$$

Similar to Proposition 1, we have

**Proposition 2** *$WTA$ is increasing in $\beta$, the informativeness of signal $S$, and the re-purchase cost $c_A$. $OV_A$ is increasing in $\beta$ and the informativeness of $S$.*

The special case of absolute irreversibility is also derived in Appendix A. In particular,

$$WTA = \bar{G} + OV_A = WTA_S + OV_A. \tag{9}$$

### 1.3 WTP/WTA and the Hicksian Measures

Two fundamental concepts of Hicksian welfare theory are compensating and equivalent variation (CV and EV). $WTP_S$ exactly equals CV and $WTA_S$ exactly equals EV for an increase in a public good or a price decrease of a private good. These correspondences are reversed when considering a decrease in the quantity of the public good or a price increase.

Since our model deals with giving up or obtaining *one* unit of the traded good, CV and EV are implicitly defined as

$$U(m - \tilde{CV}, n+1) = U(m, n) \qquad U(m + \tilde{EV}, n) = U(m, n+1), \tag{10}$$

where $\tilde{CV}$ and $\tilde{EV}$ are the CV and EV associated with one unit change in the traded good. With perfect substitution in the utility function (1), our model yields

$$\tilde{CV} = \tilde{EV} = \bar{G}. \tag{11}$$

Equations (7) and (9) make clear that the correspondences that hold between $\tilde{EV}$ and $\tilde{CV}$ and $WTP_S/WTA_S$ do not hold between $\tilde{EV}/\tilde{CV}$ and $WTP/WTA$.[9] Neither $WTP$ nor $WTA$ correctly measures the intrinsic value of the good, $\bar{G}$: they miss by their associated option values. Since only $WTP$ and $WTA$ are observable in empirical welfare measurement (not $WTP_S$ or $WTA_S$), the option values make it difficult to infer $CV/EV$ from $WTP/WTA$. That is, unlike the static case,

[9] When a trade can be reversed, we observed that even $WTP_S/WTA_S$ do not measure CV/EV correctly, due to the return and re-purchase options.

going from “behavioral observations” to “preferences” is not direct anymore: actions depend not only on intrinsic values, but also on information and the prospect of learning.

## 2 Implications for the WTP/WTA Disparity

A well known and considered puzzle in applied welfare economics is that WTP and WTA measures obtained from experimental or contingent valuation studies are typically widely divergent and these divergences cannot reasonably be explained by the magnitude of the income effects. A large literature has formed that documents this phenomenon and considers possible explanations for its occurrence. One theory that has been forwarded and gained considerable following is reference-dependent preferences (Kahneman and Tversky (1979) and Tversky and Kahneman (1991)), also variously referred to as loss aversion or endowment effects (Thaler (1980), Morrison (1997) and Morrison (1998)). This theory posits that the structure of the utility function depends upon the endowment of the consumer. Specifically, consumers are thought to value goods more highly once they own them. There are extensive experimental results that support this theory.

Another theory is due to Hanemann (1991), which demonstrates that large divergences between CV and EV (and thus WTP and WTA) can occur when there are no good substitutes for the good being valued. Experimental evidence to support this hypothesis was presented by Shogren, Shin, Hayes and Kliebenstein (1994). However, WTP/WTA divergences have been found in numerous situations that cannot be attributed to substitution effects.

Others have suggested that it may be the elicitation mechanisms used in laboratory experiments or contingent valuation surveys that induce these divergences (Shogren, Wilhelmi, Koo, Cho, Park, Polo and List (1998) and Kolstad and Guzman (1997)). Thus, the elicitation methods themselves are held to ”blame” for the WTP/WTA disparities.

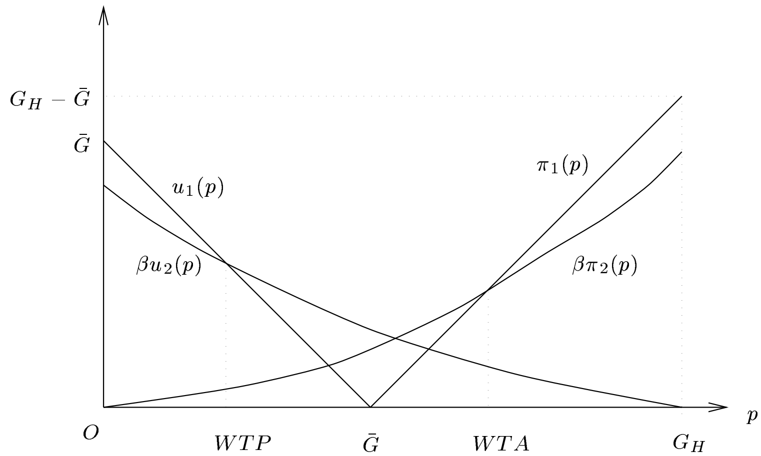



Figure 5: $WTP - WTA$ Divergence

### 2.1 An Explanation Due to Option Values

Our model provides another possible and complementary explanation for the WTP/WTA disparity. When either $OV_A$ or $OV_P$ exists, the divergence may arise even without endowment effects or the lack of substitution possibilities. The case of absolute irreversibility provides the most clear-cut example, since then both static measures ($WTP_S$ and $WTA_S$) equal the intrinsic value of the good, $\bar{G}$. Any divergence between $WTA$ and $WTP$ is due to the option value of waiting. This case is described in Figure 5. In particular,

$$WTA - WTP = OV_A + OV_P > 0, \tag{12}$$

where $OV_P$ and $OV_A$ are given in (6) and (19) respectively.

In the extreme, option values can generate divergences equal to the total intrinsic value of the good. If the agent does not have positive time preference ($\beta = 1$), her $WTP$ is zero and $WTA$ is $G_H$. Obviously if $G_H$ is large, the divergence will be significant as well.

Fundamentally our explanation results from the fact that the Hicksian equivalence between $WTA/WTA$ and $CV/EV$ breaks down in the dynamic environment we describe. Our model suggests that even if $CV = EV$, we may still have the following relationship:

$$WTP \leq CV = EV \leq WTA. \tag{13}$$

In contrast, both the endowment and substitution effects imply a direct difference between CV and EV. Both arguments implicitly accept the fundamental interpretation of CV and EV as WTP or WTA, but provide a theoretical basis for the divergence between CV and EV. Our results are thus complementary to these explanations.[10]

Based on our model, option values in Equation (12) and thus the WTP/WTA divergence arise when the following conditions are met: the agent (i) is uncertain about the value of the good, (ii) expects that she can learn more about the value in the future, (iii) has some willingness to wait (i.e. her discount factor $\beta$ is strictly positive), (iv) expects a cost associated with reversing the action of buying or selling, and (v) is forced to make a trading decision now even though she might prefer to delay the decision. Now we discuss how experiments and surveys might generate these conditions.

A "typical" laboratory experiment or contingent valuation survey might ask groups of subjects how much they would be willing to pay (or accept) to acquire (or give up) a particular good. In the case of a laboratory experiment, the good might be a deluxe chocolate bar or a specialty coffee mug.[11] In the case of a contingent valuation survey, the good might be a proposed environmental improvement. In both settings, there is uncertainty about the value of the good, and condition (i) is satisfied.

Now we discuss condition (v), especially the ability to delay. Our model in Section 1 implicitly

[10]In fact, our model can be readily expanded to incorporate these effects. A formulation based on Hanemann's specification would change the utility function in (1) to one with a lower elasticity of substitution. Endowment effects can be accommodated by changing the distribution function of $G$: an agent who owns the traded good tends to have a prior of $G$, $F_0(\cdot)$, with a higher mean.

[11]The chocolate bars typically used in these experiments are fancy, specialty bars that many subjects may have little experience in consuming. Likewise, the coffee mugs typically have university logos or other distinctive features which appear to be their primary appeal rather than their utilitarian purposes. Thus, it seems reasonable to think that typical subjects may not be certain of their valuation of these items at the beginning of the experiments.

assumes that the agent can delay her decision until period two and still have the same trading opportunities. In many lab experiments and surveys, the subjects are given choices only during the experiment or survey. It may thus appear that they do not have the ability to delay the trading decision. However, if the good used in the experiment is available in regular markets, subjects clearly have the ability to delay: instead of trading the good during the experiment, she can do so in a regular market after the experiment. Even if the good is not available outside the experiment, there may be *substitutes* with similar functions in regular markets that the subjects can trade after the experiment. Finally, even for goods without substitutes, a subject may *believe* that she will have other chances of making decisions regarding the unique good. For example, in a contingent valuation survey about a national park, a respondent may believe that she will have other chances of deciding her WTP/WTA about the park in the future, say when the government agency plans to make "real" decisions.

The information that an agent gathers in the future concerns not only the traded good itself, but also its substitutes and possibly complements. Her current uncertainty may therefore be about the value of either the traded good, or its substitutes and complements, or both. Further, the goods used in experiments and surveys are typically not urgently needed by the subjects. Compared with an actual market where consumers are actively seeking to purchase a good, subjects in an experiment or survey generally do not go to the laboratory with the intention of buying or selling a chocolate bar or coffee mug. Therefore, conditions (ii) and (iii) are often satisfied in experiments and surveys.

Finally, reversing the trade made in an experiment or survey is costly: a subject's decision is essentially irreversible within the experiment and survey sessions. She is left to herself to find ways to reverse the trade outside these sessions. This, of course, depends on the specific setting; in some cases, purchasing the good outside the experiment may be relatively easy (such as buying a coffee cup at the university bookstore), but in other cases it will be difficult (such as buying a unique oil painting). Likewise, resale markets will generally be quite poor for goods that are typically traded in experiments, but there may be situations where resale is not difficult (such as when a subject knows that his wealthy roommate is very fond of fancy chocolate bars).

Experiments and surveys have two distinctive features compared with real markets: limited time and limited learning. While in a real market a consumer may take time to gather information about the good before making her decision, a respondent in an experiment or survey must report or act upon a $WTP$ or $WTA$ value during the experiment or survey. This feature limits the respondent's learning opportunities if learning takes time. Additionally, the respondent may lack the usual ways of information gathering, such as talking to friends who have used the good or through extended observation of its use. By *forcing* the respondents to make decisions before they *voluntarily* stop information gathering, and by limiting the means of information gathering, experiments and surveys potentially increase the option values, and thus the divergence between $WTP$ and $WTA$. If this effect is significant, then option values and the $WTP/WTA$ divergence are mainly artifacts of the experiment and survey design, rather than indicating a major CV/EV divergence and the failure of expected utility or Hicksian welfare theory.

## 2.2 Predictions and Pre-existing Evidence

The magnitude of the WTP/WTA divergence depends on the size of the two option values, thus our model can make predictions about the divergence by studying how option values are affected by the characteristics of an experiment or survey. Since option values decrease as the conditions (1)-(5) listed in Section 2.1 are lessened, we know

**Hypothesis 1** *The observed divergence between $WTP$ and $WTA$ decreases as the subjects (1) are less uncertain about the good's value, (2) expect that less information can be gathered in the future* *about the good, (3) are more impatient in consuming the good or the proceeds of selling the good, (4) expect that reversing the transaction becomes easier, and (5) have more freedom in choosing when to make the decision.*

These predictions have not been directly tested in the literature. But there is some evidence from published experimental studies that lends support to some of these predictions. We discuss several representative examples of these studies and how they relate to our model.

**Level of Uncertainty**

In an insightful paper, Kahneman, Knetsch and Thaler (1990) (KKT hereafter) conducted a series of experiments to investigate the persistence of endowment effects in repeated experiments. First, several experiments (called markets) are conducted for induced-value tokens: a token can be cashed at a *predetermined* price at the end of the experiment, thus no uncertainty in the token's value exists. Next, a series of constructed markets are conducted for university coffee mugs, boxes of ballpoint pens, and folding binoculars, all available in university bookstores. KKT found no WTP/WTA divergence in token markets and persistent divergence in the other markets.

The token market results are consistent with our model predictions: since there is no uncertainty about the token's value, both option values, $OV_P$ and $OV_A$, are zero and there will be no WTP/WTA divergence. Further, we would predict that if the token is not for a *predetermined* cash amount, but for something with uncertain values, such as a lottery of cash payments, then the WTP/WTA divergence will arise. We are unaware of any experiments that directly test this hypothesis, but in an early experiment reported in Knetsch and Sinden (1984), a lottery ticket is directly traded and WTP/WTA divergences do arise, lending some support for our prediction.

**"Choosers" and the Magnitude of Option Values**

To compare what KKT call the degrees of reluctance to buy and to sell, they conducted two experiments that, in addition to "buyers" and "sellers," include a group of "choosers" who are asked to choose between a coffee mug and cash. They argue that comparing WTP and WTA with the chooser's valuation indicates the degrees of "reluctance to buy" and "reluctance to sell." They found that the median valuations are \$7.12 for sellers, \$3.12 for choosers, and \$2.87 for buyers, concluding that "there was relatively little reluctance to pay for the mug."

In the context of our model, this result can be used to estimate the range of option values. To do so, we first investigate the option value associated with a chooser's decision. If she picks the mug, her choice is essentially irreversible: she cannot return the mug and there is likely little resale possibility. Thus her expected payoff is $\bar{G}$. However, if she chooses cash, she gains the flexibility of purchasing a mug later (at the market price) when she has better information about the mug's value. Then the true value of choosing cash includes both the cash amount and the option value of still being able to buy the mug later, once she has obtained better information.[12] If the market price of the mug is $p^m$, and, as a special case, suppose she can completely learn the mug's value after the experiment, then the option value is given by $OV_{cash} = \int_{p^m}^{G_H} (G - p^m) dF(G)$, representing her expected consumer surplus.[13] She is indifferent between the mug and cash when $\bar{G} = \text{cash amount} + OV_{cash}$. Thus her reported valuation of the mug is $\bar{G} - OV_{cash}$, rather than $\bar{G}$.

Therefore the valuation of the choosers may be closer to $WTP$ than to $WTA$, simply because $OV_P$ and $OV_{cash}$ work in the same direction. The difference between WTP and the chooser's

[12]This option value is very similar to the value of a money-back guarantee. The difference is that here, instead of getting her money back by returning the good, she can get her mug back by "returning" the money. The general case of partial information updating can be handled similarly to Section 1.

[13]Suppose the subject is making a choice between $G$ and $p$, where $G$ is the value of the mug and is stochastic on $[0, G_H]$, and $p$ is the cash amount. If she chooses $G$, her expected benefit is $\bar{G}$. If she chooses $p$, she will keep the cash if $G \leq p^m$ and buy a mug if $G > p^m$. We can safely ignore discounting since it is rare that a subject happens to be in urgent need of a coffee mug. Thus her expected benefit is $p + \int_{p^m}^{G_H} (G - p^m) dF(G)$.

valuation represents a lower bound for $OV_P$, and that between WTA and the chooser's valuation represents an upper bound of $OV_A$. Therefore, KKT's result indicates that $OV_P$ is at least \$3.12 − \$2.87 = \$0.25 and $OV_A$ is at most \$7.12 − \$3.12 = \$4.00.

**Learning Within an Experiment**

In each experiment, KKT repeated the constructed market four times to allow subjects to learn about the trading institution and found that the WTP/WTA divergence persisted. In the option value model, however, "learning" is not only about the trading institutions, but more importantly about the value of the traded good, its substitutes and complements, and, generally, anything related to making the trading decision. Since there is no reason to expect that subjects will learn adequately about these values through repeated experiments, our model predicts a persistent divergence, which is consistent with their results.

For experiments that do provide adequate learning opportunities about the value of the traded good, we would expect the WTP/WTA divergence to decline over repeated trials. An example of such an experiment is found in Coursey, Hovis and Schulze (1987)(CHS hereafter). CHS conducted repeated experiments where the traded *good* is not having to taste (specifically hold in the mouth for 20 seconds) a cup of a very bitter chemical, sucrose octa-acetate (SOA).[14] Before the formal repeated trials, subjects tasted "a few sample drops" of SOA, forming the priors about the good's value. After each trial, the prevailing market price (formed from a fifth price Vickrey auction) is posted and *subjects (in particular any single winner) are allowed to demand another trial*, subject to a limit of 10 trials in total. CHS found that the WTP/WTA divergence essentially disappears in this experimental setting.

The experiment is quite unique in terms of its learning environment. First, learning about the

[14] Thus, buying the good means paying money to avoid tasting SOA while selling means getting paid for tasting SOA.

good's value can occur only within the experiment, since the good (or a substitute) is not available otherwise. Here, learning is achieved through observing posted prices, which represent how other subjects in the experiment value the good. These subjects are the only people who have tasted a sample and are thus knowledgeable about the good. Their valuation provides the only possible additional information about the good's value.[15] Second, in many cases (when the experiment stops before the tenth trial), stopping learning and making a trade is a voluntary choice of the subjects. In these cases, subjects are not *forced* to make trading decisions within a time limit.

Based on our model, subjects would voluntarily stop learning when option values are small. Our model thus predicts that the WTP/WTA divergence would become small or disappear if voluntary stopping occurs before the tenth trial. However, if the tenth trial is reached, our model would predict a larger divergence since learning has not *voluntarily* stopped, and option values may still exist. Both predictions are confirmed by CHS's results. Average WTA and average WTP are strikingly similar for experiments where subjects voluntarily cease trading before the tenth trial. For the only two experiments where WTA and WTP respectively are elicited in the tenth trial, the WTP/WTA divergence is significant.[16]

**Degree of Patience**

In most experiments the goods traded are not likely to be what a subject had in mind to purchase that day. For example, it seems unlikely that many subjects will enter an experiment only to

[15]It might be argued that since subjects have tasted the good once, no additional learning is necessary or possible. However, the "good" to be consumed is to hold the SOA in the mouth for 20 seconds which may be quite a different experience from simply having a quick taste. Further, even if a subject knows how bitter SOA is, she may still be unsure about its *value*.

[16]CHS did not report these two findings directly. We base our observation on their Figure 1, where WTA2-WTA4 and WTP1-WTP3 are elicited before the tenth trial and WTA1 and WTP4 are elicited in the tenth trial. Some researchers have argued that the use of a Vickrey auction with announced prices after each trial leads to WTP/WTA convergence since the announced prices serve as anchors for subjects (Knetsch, Tang and Thaler (1998)). Notwithstanding the anchoring effect, the fact that the WTP/WTA divergence occurs only for the two experiments where trading happens in the tenth trial still lends some support for the option value interpretation.

discover that the coffee mug they had planned to purchase later in the day is being traded in the laboratory! Subjects without a keen desire to purchase a coffee mug *now* will exhibit a high degree of patience (i.e. their $\beta$ will be high) and, based on our model, the associated option values may be high, leading to big WTP/WTA divergence.

Knetsch and Sinden (1984) briefly report (in their footnote 3) an experiment where the subjects are less patient. The traded good was a lunch and the experiment was "carried out as respondents entered an office cafeteria." Since the subjects are just in need of the traded good, delaying is costly and their patience level is low. Thus our model would predict low option values and a small WTP/WTA difference. This prediction is confirmed by the experimental result: Knetsch and Sinden (1984) found that the WTP/WTA difference was not statistically significant.[17]

**Additional Reference Points**

Bateman, Munro, Rhodes, Starmer and Sugden (1997) report the results of a carefully designed study to investigate additional predictions of reference-dependent preferences, above and beyond the divergence between WTP and WTA. They investigate four different reference points from which subjects initiate trades and show that divergences arise for some, but not all of the four cases. Again, these results are consistent with the predictions of our model.

Bateman et al. (1997) define four measures, each uniquely identified with a reference point in Figure 6. At points $a$ and $d$, the conventional $WTP$ and $WTA$ measures, denoted as $WTP_a$ and $WTA_d$, are elicited for the traded good (four cans of Coke and later 10 chocolate bars). At point $b$, "equivalent loss" $EL_b$ is elicited which measures how much a subject is willing to give up to avoid losing the good. At point $c$, "equivalent gain" $EG_c$ is used to measure how much a subject

[17]Knetsch and Sinden seemed to recognize this "patience" effect. They guessed that a possible reason for the convergence is "the fact that the respondents were already committed to spending money for a lunch at the time of their participation in the experiment."

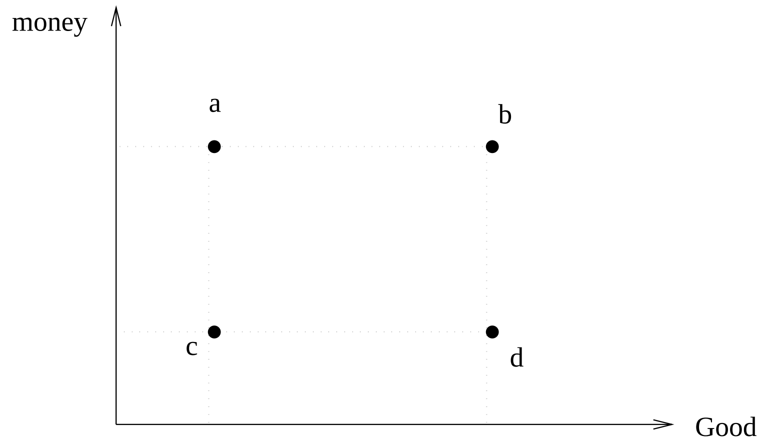



Figure 6: Reference Points in Bateman et al's Experiments

demands to be compensated for not getting the good.

Our model predicts that $WTP_a = EL_b$ since the fundamental decision a subject makes in both scenarios is to give up money for the good. Similarly, $WTA_d = EG_c$ since the common decision is to give up the good in exchange for money. Thus we predict different values between points $a$ and $d$, between $a$ and $c$, and between $b$ and $d$, and no significant difference between $a$ and $b$ and between $c$ and $d$. The experimental results of Bateman et al confirm statistically our predictions. Their econometric results indicate that, at least for the experiments where money was the numeraire, they cannot reject the equivalence of $WTP_a$ and $EL_b$ nor can they reject the equivalence of $WTA_d$ and $EG_c$.[18]

## 3 WTP/WTA Disparity in Real Markets and Final Remarks

In this paper, we presented a model of an agent's choice to purchase or sell a good under conditions of uncertainty, irreversibility, and learning over time. We examined the implications of such a

[18]See table III of Bateman et al. (1997) when money is used to elicit values. The authors also used a different response mode where Coke and chocolates are used as the unit of elicited values. They did observe different values for each reference point when the response mode is chocolate. However, errors of approximation may be significant since a subject could not choose a fraction of a chocolate bar. Moreover, their statistical test across the entire sample found no significant response mode effect (reported in their Table V).

model for welfare measurement with particular attention to the commonly used measures, WTP and WTA. These two measures, which infer value from observing actions, contain both the intrinsic value of the good, measured by CV or EV, and the option value of taking the action later with better information. Thus the Hicksian equivalence between WTP/WTA and CV/EV breaks down. The option value model provides an explanation for the anomaly of large divergences between WTP and WTA that often arise in contingent valuation and experimental settings: the divergence arises because the learning time and opportunities of the subjects are restricted in these settings.

A natural question then is whether option values, thus the WTP/WTA divergence, will arise in real markets. This has been a central question in the literature on WTP/WTA disparity. We expect that in perfectly competitive markets, option values are likely to be small if they exist at all. In market transactions, an agent is not *forced* to make a decision in any time period. Rather, she can gather information up to the point where further waiting is no longer productive (i.e. when the future signal contains little information). Consequently, we know $WTA \approx WTP \approx WTA_S \approx WTP_S \approx \bar{G}(s) \approx EV \approx CV$.[19]

In a setting where there is always the opportunity to gather at least a little more information, a consumer may never *completely* exhaust her learning opportunities before making a trade. Thus strictly speaking, the difference between $WTP/WTA$ and $EV/CV$ may be persistent. But the difference is likely to become small, especially when the transaction is repeated quite often (so that the initial uncertainty is small). Further, in real markets consumers may be impatient if they are actively seeking to make a transaction. In the extreme, option values completely vanish if the consumers are very impatient (with $\beta = 0$) — the case for desperate last minute shoppers, hungry tourists, or a variety of other common situations.

[19] Alternatively, in an imperfectly competitive market, firms may offer price discounts to consumers. In this case, the agent may voluntarily stop waiting and make the trade either when the price discount is attractive enough, or when no further information can be gathered. The disparity persists in the first scenario, but disappears in the second.

The existence of option values has important implications for empirical welfare analysis, especially when experimental or survey data are used. Option values may be induced (probably inadvertently) by the researcher who, for example, forces a time limit on an experimental subject or inaccurately overstates uncertainty in a contingent valuation question. Such analysis-induced option values generally do not provide relevant valuation information. Thus, estimated WTP and WTA will need to be modified by the option values to provide policy relevant welfare measures.

However, there are cases where the value of interest is WTP or WTA, inclusive of the relevant option values. Some decisions are inherently characterized by uncertainty and irreversibility, and therefore contain "real options" that are not analysis-induced, but rather are characteristic of the real situation. For example, a graduate student who is given one week to decide on a job offer has to consider the associated option values in making her decision. Additionally, a decision to build an elementary school or local hospital this year will likely have policy-relevant option values.[20] In these cases, an experiment or survey that accurately replicates the real market features will elicit WTA and WTP measures that contain the option values. But these option values represent real uncertainty and should enter the welfare calculations, thus WTA or WTP are in fact appropriate welfare measures. Public good examples where appropriate welfare measures include option values abound and, in fact, prompted the Arrow and Fisher (1974) inquiry into real options.[21]

We also discussed some pre-existing evidence from published experimental studies that provides intriguing empirical support for the existence of option values in WTP and WTA. However, since these studies were not designed *ex ante* with specific hypotheses related to option theory in mind, further empirical verification is needed before it can be concluded that option values are significant parts of WTP and WTA, and provide a major explanation for the WTP/WTA disparity.

[20] Note again the similarity to the real options theory of investment where option values are important components of an investment decision.

[21] In a companion paper, we investigate specifically dynamic welfare measurement when option values are important.

# A Model Details

This appendix contains the details of the WTP/WTA model. We assume that the density function of $G$, $f(\cdot)$, is continuous and bounded away from zero. This guarantees that $V(p,s)$, $u_1(p)$ and $u_2(p)$ are continuous and strictly decreasing in $p$.

**Sufficient condition for** $u_2(p) > u_1(p)$

Now we describe a sufficient condition for $u_2(p) > u_1(p)$ when $p > 0$.[22] For $p \in (0, G_H]$ and $\delta < 1$, let $S(p,\delta) = \{s \in S : \text{Prob}_{G|S}(G \in [0,p)|s) > \delta\}$ be the set of signals which predict that the good's value will be below price $p$ with a probability higher than $\delta$.

**Assumption 1** *For any* $p \in (0, G_H]$ *and any* $0 \leq \delta < 1$*, the set* $S(p,\delta)$ *has a positive probability measure.*

This assumption essentially ensures that for any price $p > 0$, there are always some signals which would predict that the good's value will be most likely below the price. The agent should not buy the good if these signals are realized. Since these signals will realize with a positive probability, delaying will always be beneficial without discounting, that is, $u_2(p) > u_1(p)$ for $p > 0$. Proposition 3 shows that this intuition is correct.

**Proposition 3** *Assumption 1 implies that* $u_2(p) > u_1(p)$ *for* $p \in (0, G_H]$.

[22] We thank Subir Bose for pointing out this sufficient condition.

**Proof.** Choose any $p^* \in (0, G_H]$ and set the corresponding $\delta^* = 1 + \frac{\int_0^{p^*} \max\{-c_P, G-p^*\} dF_{G|S}(G)}{G_H - p^*} < 1$. We only need to show that $V(p^*, s) < 0$ for $s \in S(p^*, \delta^*)$. This is true since

$$\begin{aligned} V(p^*, s) &= \int_0^{p^*} \max\{-c_P, G-p^*\} dF_{G|s}(G) + \int_{p^*}^{G_H} \max\{-c_P, G-p^*\} dF_{G|s}(G) \\ &\leq \int_0^{p^*} \max\{-c_P, G-p^*\} dF_{G|S}(G) + (G_H - p^*) \mathrm{Prob}_{G|S}(G \in [p^*, G_H]|s) \\ &< \int_0^{p^*} \max\{-c_P, G-p^*\} dF_{G|S}(G) + (G_H - p^*)(1-\delta^*) < 0. \end{aligned} \quad (14)$$

The second inequality follows from the fact that for $s \in S(p^*, \delta^*)$, $\mathrm{Prob}_{G|s}(G \in [p^*, G_H]|s) > \delta^*$. The last inequality follows from the definition of $\delta^*$. ■

**Existence and uniqueness of $p_P$**

Let $d(p) = \beta u_2(p) - u_1(p)$, where $\beta < 1$. To show the existence and uniqueness of $p_P$, we only need to show $d(p) = 0$ has a unique solution on the interval $[0, G_H]$. We know $d(0) < 0$ since $u_2(0) = u_1(0) > 0$, and $d(G_H) > 0$ since $u_2(G_H) = 0$ and $u_1(G_H) < 0$. Thus a sufficient condition for existence is that $d(\cdot)$ is continuous on $[0, G_H]$, and a sufficient condition for uniqueness is that $d(\cdot)$ is strictly increasing on $[0, G_H]$.

Note that $V(\cdot, s)$ is continuous for all $s \in S$. Then (3) implies that $u_1(\cdot)$ is continuous. Since $\max(\cdot)$ is a continuous operator, (4) implies that $u_2(\cdot)$ is continuous. Therefore, $d(\cdot)$ is continuous and $p_P$ exists.

To show the monotonicity of $d(\cdot)$, we first demonstrate that $u_2(p) - u_1(p) = -\int_{S_{P2}(p)} V(p, s) dH(s)$ is increasing in $p$. Suppose $p_2 > p_1$. Since $V(p, s)$ is strictly decreasing in $p$, we know $V(p_2, s) < V(p_1, s)$ and $S_{P2}(p_2) \supset S_{P2}(p_1)$. Thus $u_2(p_2) - u_1(p_2) > u_2(p_1) - u_1(p_1)$, or $u_2(p_2) - u_1(p_2) = (1-\beta)u_2(p_2) + d(p_2) > u_2(p_1) - u_1(p_1) = (1-\beta)u_2(p_1) + d(p_1)$. Since $u_2(p)$ is decreasing in $p$, we know $d(p)$ is strictly increasing in $p$ and $p_P$ is unique.

**Proof of Proposition 1**

Since $d(\cdot)$ is strictly increasing on $[0, G_H]$, we know $p_P$, thus $WTP$, decreases when the curve $d(\cdot)$ is shifted up. Thus $WTP$ is decreasing in $\beta$. Since $WTP_S$ is independent of $\beta$, $OV_P = WTP_S - WTP$ is increasing in $\beta$.

Kihlstrom (1984) shows that $u_2(p)$ increases as the signal service $S$ becomes more informative about $G$ in the sense of Blackwell (1951 and 1953). Thus $WTP$ is decreasing and $OV_P$ is increasing in the informativeness of $S$.

To show the effect of $c_P$, note that $u_2(p) - u_1(p) = -\int_{S_{P2}(p)} V(p,s)dH(s)$ is strictly increasing in $c_P$, since $V(p,s)$ is strictly decreasing in $c_P$. However, $u_2(p) - u_1(p) = (1-\beta)u_2(p) + d(p)$, and $u_2(p)$ is strictly decreasing in $c_p$. Thus $d(p)$ is strictly increasing in $c_p$. That is, $WTP$ is decreasing in $c_P$.

**The special case of absolute irreversibility**

To derive (6) and (7), we substitute $u_1(p) = \bar{G} - p$ and $u_2(p) = u_1(p) - \int_{S_{P2}} (\bar{G}(s) - p)dH(s)$ into $u_1(p) = \beta u_2(p)$, and solve for $p$. We then get

$$p_P = \frac{(1-\beta)\bar{G} + \beta \text{Prob}(S_{P2}) E(G|S_{P2})}{1 - \beta + \beta \text{Prob}(S_{P2})}.$$

(6) and (7) then directly follow.

**Derivation of $WTA$**

The net benefit of selling, $W(p,s)$ is defined as

$$\begin{aligned} W(p,s) &= \int_0^{G_H} (\max\{G - c_A, p\} - G)\, dF_{G|s}(G) \\ &= \int_0^{G_H} \max\{-c_A, p - G\} dF_{G|s}(G). \end{aligned} \tag{15}$$

Note that for $p > G_H - c_A$, $W(p,s) = p - \bar{G}(s)$.

The definition of $\pi_i(p)$, $i = 1, 2$ is given by

$$\pi_1(p) = W(p, 0) = \int_S W(p, s) dH(s) \tag{16}$$

$$\pi_2(p) = \int_S \max\{0, W(p, s)\} dH(s) = \int_{S_{A2}(p)} W(p, s) dH(s), \tag{17}$$

where $S_{A2}(p) = \{s \in S : W(p, s) \geq 0\}$ is the set where the realized signals indicate that selling is desired. We define $S_{A1}(p) = S \backslash S_{A2}(p) = \{s \in S : W(p, s) < 0\}$. $\pi_1(p) < \pi_2(p)$ as long as $S_{A1}(p)$ has a positive probability measure. We make necessary assumptions parallel to Assumption 1 to guarantee that this is true.

The proof of Proposition 2 is similar to that of Proposition 1.

The special case of absolute irreversibility occurs if $c_A \geq G_H$. Similar to the case of $WTP$, we can get

$$WTA_S = \bar{G} \tag{18}$$

$$OV_A = \frac{\text{Prob}(S_{A1})}{\frac{1}{\beta} - \text{Prob}(S_{A2})} \left[ E(G|S_{A1}) - \bar{G} \right], \tag{19}$$

and (9). Note that $E(G|s) > \bar{G}$ for all $s \in S_{A1}$, since $S_{A1}$ is the set in which realized signals predict high $G$ values (thus no sale is made). Consequently, $OV_A > 0$.

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