WILLINGNESS TO PAY, COMPENSATING VARIATION, AND THE COST OF COMMITMENT

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Hicksian welfare theory is static in nature, but many decisions are made in a dynamic environment. We present a dynamic model of an agent's decision to purchase or sell a good under the realistic conditions of uncertainty, irreversibility, and learning over time. Her willingness to pay (WTP) contains both the intrinsic value of the good as in Hicksian theory plus a commitment cost associated with delaying to obtain more information. The Hicksian equivalence between WTP/Willingness to accept (WTA) and compensating and equivalent variations no longer holds. The WTP and WTA divergence may arise and observed WTP values are not always appropriate for welfare analysis. (*JEL* D60, D83)

I. INTRODUCTION

Hicksian welfare theory, which is static in nature, forms the basis of modern welfare analysis. This theory has provided a wealth of compelling principles with direct applicability for empirical welfare analysis (see, for example, Hoehn and Randall 1987; Bockstael and McConnell 1983; Randall and Stoll 1980). The equivalence of the maximum willingness to pay (WTP) for a good with the Hicksian concept of compensating (or equivalent) variation (CV or EV) is a central precept of this theory. This specific principle has provided the necessary theoretical basis for substantial literature in several areas of applied economics, including work on valuing public goods, experimental economics, and price discriminating monopoly, to name only a few.

Thus, researchers in search of the value of a public good have designed surveys eliciting consumers' maximum WTP to obtain the public good. If the assumptions of the static Hicksian theory hold, this measure can be readily interpreted as the compensating variation, a theoretically defensible welfare measure that can be directly applied to cost-benefit analysis using stated preference methods (Mitchell and Carson 1989; Carson 1997; Smith 2000). Likewise, experimental economists elicit WTP or willingness to accept (WTA) based on actual transactions to test a variety of consumer theory hypotheses, including the empirical disparity between WTP and WTA (Horowitz and McConnell 2002; Horowitz et al. 1999; List forthcoming) and the equivalence between revealed and stated preference values (Cummings and Taylor 1999; List 2001).

However, many decisions in the real world are made in dynamic settings: Purchase decisions may be delayed while information is gathered, purchase "mistakes" can be reversed by return policies, and there are often costs associated with these transactions. In this article we explore the Hicksian concepts of compensating and equivalent variation as well as WTP (and WTA) in explicitly dynamic situations; specifically, where the agent is uncertain about the value of the good under consideration but can latter

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ABBREVIATIONS

CV: Compensating Variation
CVM: Contingent Valuation Method
EV: Equivalent Variation
QOV: Quasi-Option Value
WTA: Willingness to Accept
WTP: Willingness to Pay

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obtain more information about it. We find that, although CV and EV have natural expected value counterparts that are conceptually akin to the static CV and EV, their relationship to the WTP and WTA concepts becomes much more complicated. Specifically, in addition to CV/EV, WTP and WTA will also depend critically on a variety of factors related to the timing of the formation of these values. Even if expected CV and EV are unchanging with the acquisition of new information, WTP and WTA will generally not be. Thus, at any point in time, WTP or WTA will not be equivalent to the expected CV or EV.

The intuition behind the breakdown of the equivalence between CV/EV and WTP/WTA in an intertemporal setting has to do with the nature of the measures themselves. The Hicksian concepts of CV and EV can be thought of as measuring the intrinsic value of a good. Specifically, CV measures the amount of compensation necessary after a change in price or other attribute that holds the consumer's utility constant. Consequently, this measure depends only on the utility function itself, not on the timing of a transaction or any other characteristics of the exchange environment.

In contrast, the consumer's WTP (or WTA) for a good is a fundamentally behavioral concept. The behavior in question is that of buying (or selling) a good. How much one is willing to pay (or accept) for a good at a particular point in time will depend on a variety of factors, including, of course, the expected intrinsic value. However, also included will be the consumer's rate of time preference, the ability to reduce the risk of a bad purchase or sale by gathering more information, and the ease of later reversing the transaction if so desired. Note that all of these features are related in some way to the timing of the behavioral decision. Thus, in a static model, the behavioral concepts collapse to the intrinsic Hicksian measures. However, in an explicitly dynamic setting, the equivalence between Hicksian values and the behavioral WTP/WTA values will not necessarily hold.

In practice, in many markets 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.[1] 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 prices of substitutes) and to solidify their own preferences for the good. The information helps the agent reduce the likelihood of having to reverse a trade (thus incurring the associated transaction cost) later on. 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 he or she might if he or she waited and gathered further information. Alternatively, for the art collector to sell the painting to the first bidder and forgo further learning, he or she will demand a higher price in 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 (CV or EV) and how quickly the decision has to be made (or the amount of information available).

In this article we present a model that explicitly demonstrates the effect that timing of an action can have on WTP and WTA. Specifically, by *committing* to a purchase or sale decision, the agent has to abandon learning opportunities and thus demands appropriate "compensation." Consequently, the WTP for a commodity will be reduced by a commitment cost, and the agent's WTA will be increased by another commitment cost. Readers familiar with the real options literature in investment theory will recognize that these commitment cost concepts are related to option values arising in investment decisions. As Arrow and Fisher (1974), Henry (1974), Epstein (1980), Kolstad (1996), and Dixit and Pindyck (1994) have demonstrated, this role of future information means that there is a benefit, called quasi-option value (QOV),[2] associated with waiting to make a decision. Later, we demonstrate how the commitment costs are related to and distinct from QOV. More important, this article develops a systematic framework for

1. In fact, the literature on herd behavior focuses explicitly on information and the timing of decisions by a group of agents (Banerjee 1992; Bikhchandani et al. 1992).

2. QOV is distinct from the option value concept in the option price literature (Ready 1995). It measures a conditional value of information and exists even for risk neutral agents. See Hanemann (1989) for additional discussion of QOV. Dixit (1992), reviewed in Hubbard (1994), provides a nice review of the QOV literature, and Fisher (2000) establishes the equivalence between the Arrow-Fisher-Henry model and the Dixit and Pindyck (1994) framework.

studying the effects of uncertainty, irreversibility and new information in consumer welfare analysis. Because commitment costs, in addition to the intrinsic value of the good (i.e., CV or EV), enter the WTP/WTA measurement, the standard relationship in Hicksian welfare theory between the WTP/WTA and CV/EV fails to hold.

The article is organized as follows. Section II 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 commitment costs and variables that affect the magnitude of these commitment costs are examined. In section III, we investigate the relationship between WTP/WTA and CV/EV. In Section IV, we discuss some of the implications of these theoretical results for applied welfare analysis.

II. A MODEL OF WTP/WTA FORMATION

In this section, we model a situation typical of real-world welfare economic problems, namely, an agent's decision to purchase or sell a good when the good has uncertain value to the agent. However, unlike the Hicksian framework, we assume that information becomes available over time that reduces this uncertainty, and the agent can purchase the good either now or later when more information arrives. 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

$$U(m,n) = m + nG, \quad (1)$$

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, we impose the condition that $n \in \{0, 1\}$, that is, the agent can only trade *one unit* of the specific good.[3]

Suppose the agent can trade in either period 1 (current) or 2 (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 $[0, G_H]$.[4] She knows that more information about G will be available in period 2, and specifically, the information comes in the form of a *signal* about G, denoted by $s \in S \subset \mathscr{R}$, 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 2 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, that is, $h(s) = \int_0^{G_H} h_{s|G}(s)dF_0(G)$, and let $H(\cdot)$ be the corresponding distribution function. Observing s, the agent updates her belief about G according to Bayes's 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.[5] She has some idea (described by her prior F_0) about its value to her, but before making an offer, she wishes to consult a 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 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.[6] 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 repurchasing the good. Ex post, it may be

3. This assumption allows us to work with the constant marginal utility function in (1) without imposing a budget constraint. Otherwise, we need to work with a more general utility function with decreasing marginal utility. The assumption greatly simplifies our analysis and does not affect our major results.

4. Without loss of generality, we let the lowest possible value of G be zero. We could use a more general representation, such as $G_L(< G_H)$, and the results would remain the same.

5. This example is based on the painting experiments performed by Neill et al. (1994), where paintings were offered for sale to subjects who used their own money to (or not to) purchase paintings that were exhibited in the experiments.

6. 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 resold it. We assume away the time lag between trading and the realization of G, without affecting the major results of our model.

desirable to return the good and incur c_P if G turns out to be quite low and repurchase 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.

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* factor, we assume that she discounts the second period benefit at rate $\beta \in [0, 1]$. Note that β 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 β) if, say, she needs the painting for a party the next day. But her β 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 opportunity 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:

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 because 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 unique 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 unique 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 $WTA = p_A$.

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,

$$(2) \quad V(p,s) = \int_0^{G_H} \max\{p - c_P, G\} dF_{G|s}(G) - p = \int_0^{G_H} \max\{-c_P, G - p\} dF_{G|s}(G).$$

The integrand, $\max\{p-c_P, G\}$, represents the agent's ex post payoff from either keeping the good (thus getting G) or returning 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).[7] That is, $V(p,0) = \int_0^{G_H} \max\{-c_P, G-p\} dF_0(G)$.

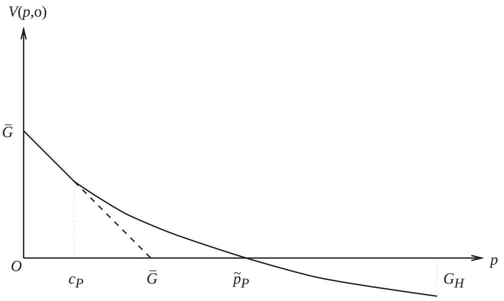
Because $\max(\cdot)$ is a convex operator, we know $V(p, s)$ is decreasing and convex in p. If $p \leq c_P$, $\max\{-c_P, G - p\} = G - p$ for all $G \in [0, G_H]$ (i.e., the agent will never return the good). In this case $V(p, s) = \bar{G}(s) - p$ where $\bar{G}(s) = \int_0^{G_H} G dF_{G|s}(G)$ is 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. Note that as long as $f_{G|s}(\cdot)$ is strictly positive, almost surely on $[0, G_H]$, $V(p, s)$ is strictly decreasing in p for $p < G_H$. Even when p is close to G_H, there is always a positive probability that $G - p > -c_P$ (e.g., when G is close to G_H), causing $V(p, s)$ to be decreasing in p. For technical clarity, we assume throughout that $f_{G|s}(\cdot)$ is bounded away from zero on $[0, G_H]$ for all $s \in S$.

Figure 1 graphs $V(p, 0)$, where $\bar{G}$ stands for $\bar{G}(0)$. Because $V(p, 0) = 0$ 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.[8] It is

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

8. 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 et al. (forthcoming).

FIGURE 1
Static Welfare Measurement: *WTP*



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 in greater detail 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 1 (without any signal). Then

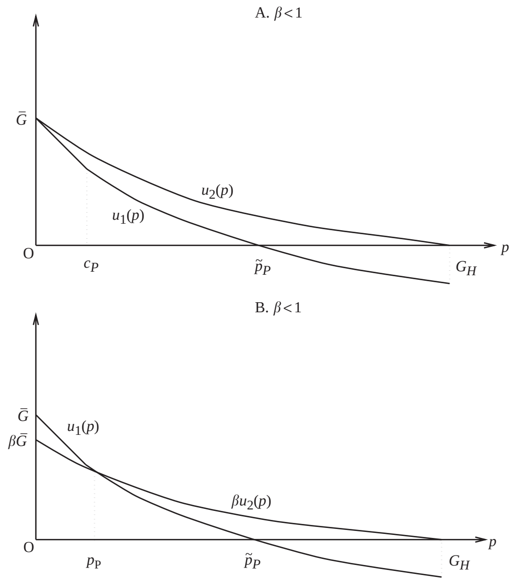
$$(3)\quad u_1(p) = V(p,0) = \int_S V(p,s)dH(s).$$

Let $u_2(p)$ be her expected net surplus if at price p, she does not buy in period 1 but instead makes her decision in period 2. Observing s, the agent will buy the good only if her expected 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 1 is

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

where $S_{P1}(p) = \{s \in S : V(p,s) \geq 0\}$. Because $V(p,s)$ is decreasing and convex in p, so are $u_1(p)$ and $u_2(p)$. [$u_2(\cdot)$ is convex because $\max\{\cdot,\cdot\}$ is a convex operator.] Comparing (3) and (4), we know $u_1(p) \leq u_2(p)$ for all $p \in [0, G_H]$, and the inequality is strict if $S_{P1}(p)$ has a probability measure of less than one. The appendix 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 below p with at least a certain strictly positive probability. We assume that this condition is

FIGURE 2
Dynamic Welfare Measurement: *WTP*



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 signal s falls in the "no-purchase" set, $S_{P2}(p) = S/S_{P1}(p) = \{s \in S : V(p,s) < 0\}$.

Figure 2A graphs both $u_1(p)$ and $u_2(p)$. Note that $u_2(0) = u_1(0) = \bar{G}$ because 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. Further, $u_2(G_H) = 0$ because 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 signal, and the net benefit is zero.

In fact, Figure 2A illustrates the optimal decision when there is no discounting. Because $u_2(p) > u_1(p)$ for $p > 0$, the agent always waits for the signal if $p > 0$. This result is obvious: Because 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 2B. 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 $WTP = p_P$. The appendix shows that p_P exists and is unique.

WTP is closely related to the Arrow-Fisher-Henry QOV given by $QOV(p) = \max\{0, \beta u_2(p) - u_1(p)\}$. For a given price p, QOV measures the additional benefit of being able to wait for the new information, conditional on the fact that waiting is optimal (Hanemann 1989). Then the WTP is the maximum price at which QOV is zero.[9] 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 article, we define a distinct concept of "commitment cost" that measures the difference between the static and dynamic WTP: $CC_P = \tilde{p}_P - p_P \geq 0$, or written differently,

$$(5) \qquad WTP = WTP_S - CC_P.$$

This commitment cost measures the compensation, in terms of a lower price (for both periods), that the agent demands to give up the opportunity of waiting by buying the good now. It represents the minimum amount of money needed, in terms of an overall price reduction, to induce the agent to buy in this period. Conceptually, it is similar to $QOV(\tilde{p}_P)$: given price $\tilde{p}_P$, both QOV and CC_P measure how much is needed to induce the agent to buy in the current period. The difference is that QOV is expressed in terms of a direct income transfer, whereas CC_P is expressed in terms of a price cut for both periods, thus allowing application to modeling consumer welfare measurement. Zhao and Kling (2002) establish a monotonic functional relationship between the two measures.

Consider again the painting example. Suppose the listed price of the painting is $\tilde{p}_P$. Without the opportunity 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: 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 CC_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, whereas the price change in determining CC_P lasts for at least two weeks. Thus, QOV is measured in direct income transfer, and CC_P is measured in (permanent) price discounts.

The reason for the monotonic relationship between CC_P and QOV is that the two measures are derived from the same decision problem, that is, making a purchase facing uncertainty, irreversibility, and future learning. To decide when to purchase the good, the QOV literature takes as given the cost (or price), and looks for the *signals s* that will lead to the purchase. In our model, we study the same problem but flip the question: Given the possible signals, at what cost (or price) should the agent purchase the good. Both CC_P and QOV require the same conditions to arise, namely, uncertainty, costly reversibility, future learning, and the ability to delay the decision. Although the QOV literature emphasizes the investment decision rules, by asking the flip side of the QOV question, we focus on the welfare measure in the dynamic purchase decision, rather than on the decision rule itself.[10]

WTP and CC_P depend on the incentive of the agent to wait for new information. Intuition suggests that this incentive rises as the agent becomes more patient (has a lower discount rate), as the future signal becomes more informative about the good, or as the cost of returning the good (or the penalty

9. Strictly, $WTP = \inf\{p \in [0, G_H] : QOV(p) > 0\} = \inf\{p \in [0, G_H] : \beta u_2(p) > u_1(p)\}$.

10. This relationship between CC_P and QOV is established for the case where the quantity traded is exogenously fixed. When the agent can freely choose how much to buy, the optimal quantity is one at which the associated QOV is just zero (see, e.g., Dixit and Pindyck 1994). Similarly, we can show that the commitment cost at this quantity is also just zero. The intuition is that when quantity purchased is small, the possible loss from committing without further information is small relative to the gain from acting early. The agent then needs no compensation for buying now. However, compensation is needed for large quantities, either in the form of a QOV or a CC_P. Therefore, CC_P and QOV are different forms of the compensation needed for early actions both for fixed and for endogenous quantities. Here we model a fixed quantity mainly to be consistent with the majority of lab experiments and CVM surveys: Subjects routinely are required to buy/sell fixed quantities of goods in experiments, and CVM surveys are often used to estimate the welfare effects of exogenously given quantity changes.

for making a bad purchase) increases. Proposition 1 (proved in the appendix) 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 β, the informativeness of signal S, and the return cost* c_P. CC_P *is increasing in β and the informativeness of S.*

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 CC_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.

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 $WTP_S = \bar{G}$. The appendix shows that

$$(6) \qquad CC_P = [\text{Prob}(S_{P2})/([1/\beta] - \text{Prob}[S_{P1}])] \times [\bar{G} - E(G|S_{P2})], \quad \text{and}$$

$$(7) \qquad WTP = \bar{G} - CC_P = WTP_S - CC_P,$$

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

The Determination of WTA

The derivation of WTA, shown in the appendix, is 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 static WTA measure, WTA_S. Again $\tilde{p}_A < \bar{G}$ due to the "goods-back guarantee". Because 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.

FIGURE 3
Static Welfare Measurement: *WTA*

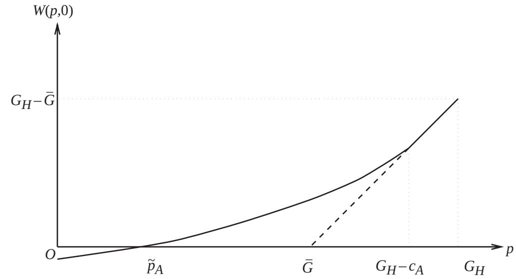
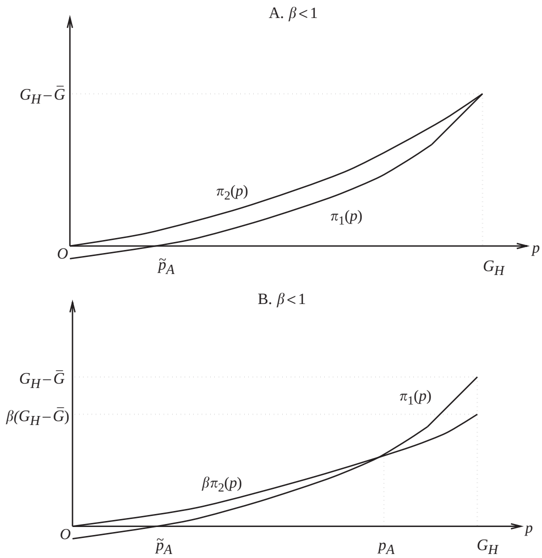


FIGURE 4
Dynamic Welfare Measurement: *WTA*



Let $\pi_1(p)$ and $\pi_2(p)$ be the agent's expected net surplus if she decides to sell the good in period 1 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 the commitment cost of selling now as $CC_A = p_A - \tilde{p}_A \geq 0$, we know

$$(8) \qquad WTA = WTA_S + CC_A.$$

Similar to Proposition 1, we have

PROPOSITION 2. *WTA is increasing in β, the informativeness of signal S, and the repurchase cost c_A. CC_A is increasing in β and the informativeness of S.*

The special case of absolute irreversibility is also derived in the appendix. In particular,

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

III. WTP/WTA AND THE HICKSIAN MEASURES

We now relate the dynamic measures WTP and WTA to the Hicksian welfare measures CV and EV. Because our model deals with giving up or obtaining *one* unit of the traded good, CV and EV are implicitly defined as

$$\begin{aligned} EU(m - \tilde{CV}, 1) &= EU(m, 0) \\ EU(m + \tilde{EV}, 0) &= EU(m, 1), \end{aligned} \tag{10}$$

where $\tilde{CV}$ and $\tilde{EV}$ are the CV and EV associated with one unit change in the traded good.[11] 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*.[12] Neither *WTP* nor *WTA* correctly measures the intrinsic value of the good, $\bar{G}$: They miss by their associated commitment costs. Because only *WTP* and *WTA* are observable in empirical welfare measurement (not *CV* or *EV*), the commitment costs make it difficult to infer *CV*/*EV* from *WTP*/*WTA*. That is, unlike the static case, going from "behavioral observations" to "preferences" is not direct anymore: Actions depend not only on intrinsic values but also on commitment, information, and the prospect of learning.

The existence of commitment costs indicates that some of the properties of CV and EV cannot be carried over to WTP and WTA. For example, WTP and WTA will not necessarily share the symmetry that CV and EV exhibit related to a reverse welfare change. The CV for a change from bundles A to B exactly equals the EV for a change from B to A. However, different directions of irreversibility and thus differences in CC_A and CC_P imply that the WTP for a change from A to B will not necessarily equal the WTA for a change from B to A. It is therefore important in applied welfare analysis to find out whether commitment costs exist and, if so, their magnitudes. Next, we discuss several cases where new insights can be obtained from applying our dynamic welfare measurement framework.

IV. IMPLICATIONS

Based on our model, commitment costs arise when the following conditions are met: the agent (1) is uncertain about the value of the good, (2) expects that she can learn more about the value in the future, (3) has some willingness to wait (i.e., her discount factor β is strictly positive), (4) expects a cost associated with reversing the action of buying or selling, and (5) is forced to make a trading decision now even though she might prefer to delay the decision. Commitment costs and the difference between WTP/WTA and CV/EV are larger as each of these factors become stronger.

In this section, we highlight a few of the implications these results have for welfare analysis. We discuss situations in which commitment costs may arise and be relevant. Although separate analysis would be needed to formally explore the applications in each area, we focus on intuitive descriptions of why commitment costs may be important in that particular application.

Before beginning, we note that although we only modeled uncertainty about the marginal utility of the traded good, our model applies to cases where the agent is uncertain about the prices of the good in other stores and the prices of complement and substitute goods. Similarly, her future learning may be about the utility and relevant price information. The following discussion will be based on this more general interpretation of uncertainty.

11. Because we are measuring the welfare effects of a quantity change, $\tilde{CV}$ and $\tilde{EV}$ are in fact *compensating surplus* and *equivalent surplus*, respectively (Randall and Stoll 1980). Because they are conceptually similar to CV and EV, we follow standard usage (Hanemann 1991) and continue to use the terms CV and EV.

12. 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 repurchase options.

WTP/WTA Divergence in Experiments and Surveys

A well-known and considered puzzle in applied welfare economics is that WTP and WTA measures obtained from experimental and contingent valuation studies are typically widely divergent and these divergences cannot reasonably be explained by the magnitude of the income effects.[13] These findings have seriously challenged Hicksian welfare theory: Using a meta-analysis of over 200 WTA and WTP observations from 45 experiments and surveys, Horowitz and McConnell (forthcoming) found *no* preference structure in the Hicksian framework that is consistent with the observed WTA and WTP ratio. The WTP/WTA divergence identified in contingent valuation surveys has been implicitly viewed as evidence of the failure of the survey methods—because it conflicts with the Hicksian theory! The divergence has prompted the NOAA panel to recommend using WTP as the welfare measure regardless of the property rights involved (Arrow et al. 1993).

There have been several attempts to explain this WTP/WTA divergence. One theory that has been forwarded and gained considerable following is reference-dependent preferences, also variously referred to as loss aversion or endowment effects (Kahneman and Tversky 1979; Tversky and Kahneman 1991). This approach is inconsistent with Hicksian theory and posits that the structure of the utility function depends on the endowment of the consumer: She values goods more highly once she owns them. Her indifference curves for different endowments will cross. Numerous experiments have been conducted, and their results interpreted as supporting this theory over neoclassical preferences (Harbaugh et al. 2001; Horowitz and McConnell 2002).

Another explanation is due to Hanemann (1991), who builds on Randall and Stoll (1980) and 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. Others have suggested that it may be the process of preference formation (Hoehn and Randall 1987) or the auction mechanisms used in laboratory experiments that induce these divergences (Kolstad and Guzman 1999). These explanations operate within the Hicksian framework but are limited in their applications.[14]

All of these explanations implicitly assume that WTP/WTA obtained based on agents' behaviors accurately measures the intrinsic welfare CV/EV and interpret any difference between WTP and WTA as that of CV and EV. Our results provide a different, and in some sense complementary explanation for the WTP/WTA disparity. When either CC_A or CC_P exists, the divergence may arise even without endowment effects or the lack of substitution possibilities. That is, even if $CV = EV$, we may still have the following relationship:

$$WTP \leq CV = EV \leq WTA. \tag{12}$$

Because both the endowment and substitution effect arguments implicitly accept the fundamental interpretation of CV and EV as WTP or WTA, if indeed a divergence exists between CV and EV due to these effects, our results imply that the observed divergence between WTP and WTA would be even bigger, over and above that between CV and EV. In this sense, our explanation is complementary to the existing ones.[15]

Therefore, for our model to explain (at least partially) the WTP/WTA divergence, we only need to investigate whether the experimental and survey settings give rise to at least one of the commitment costs CC_A and CC_P. In a companion paper (Zhao and Kling 2001), we argue that experiments and surveys in general satisfy conditions (1)–(5) (specified at the beginning of this section) needed for commitment costs to arise. Specifically, they require a subject to make a decision (buying/selling in experiments and a particular answer in surveys) within a certain time frame (within the experiment or survey session), forgoing future learning opportunities. The decision is typically irreversible, and the subject is willing to postpone the

13. See Horowitz and McConnell (2002) for a nice review of the literature on these divergences and Hammack and Brown (1974) for one of the first contingent valuation illustrations.

14. For example, Hanemann's theory cannot explain the divergence in experiments where the traded good, usually a coffee mug, a pen, and so on, has many good substitutes. Kolstad and Guzman (1999) does not apply to experiments where the auction mechanism is not used.

15. Our model can be expanded to incorporate these considerations. 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.

decision. Together, these conditions can lead to commitment costs in these settings. In fact, we showed that in some special cases, the commitment costs can generate divergences twice the total intrinsic value of the good. The essence of this explanation is that the WTP/WTA divergence may have been induced by the limited information and learning opportunities in experiments and survey settings and is not necessarily inconsistent with neoclassical preferences or Hicksian welfare theory.

Zhao and Kling (2001) discussed in detail published experimental results that are consistent with our hypothesis. Here we focus on contingent valuation method (CVM) surveys and briefly discuss how commitment costs can arise and lead to inaccurate welfare measurement.

CVM surveys are mainly used to measure *values* of certain environmental goods or improvements, but the survey questions are often in the form of *decisions* for the subjects to make. For example, the researcher may be interested in the value of clean water or the welfare gains from improved water quality in a polluted lake. The survey question may be "are you willing to pay $X for a project that will improve the water quality to a certain level?" with X varied across surveys. The researcher's interest is not in the subject's decision itself but the implied welfare measures of the decision. (Later we will discuss cases in which the interest is exactly in the decisions rather than in the values.)

Once a subject is faced with this *decision*, he will consider factors that will affect his optimal choice but are not directly related to the expected value of the project. He may be uncertain about the value of improved water quality, depending on how often he will visit the lake, the exact future water quality, his future income, how many others will be visiting the lake, and the water quality in other lakes (substitutes). He may expect that more (likely not perfect) information about these factors will be available in the future, enabling him to make a better judgment about his decision. He may foresee that (at least with a positive probability) the project (or a substitute project) may be proposed in the future even if the proposed CVM 'referenda' were not to pass at this time. That is, he may believe that the "purchase" of better water quality can be delayed even if that means undertaking the transaction outside of the CVM instrument. Thus, he may be unwilling to commit payment now. However, the subject has to answer the survey question within a set time frame, forgoing learning opportunities. As a result, commitment cost will arise and affect his decision/response.

If the researcher is interested in the subject's valuation of improved water quality given the current information, this commitment cost should not be part of the valuation and is policy-irrelevant. Thus, if the welfare measure computed by the analyst from a set of such responses is used in a benefit-cost analysis determining whether to undertake the project now, the welfare measure will understate the true benefits, by the amount of the commitment cost. By posing a decision and inadvertently forcing a time limit on making the decision, CVM surveys may lead to inaccurate welfare measurement.

Furthermore, in many CVM surveys, the effects of a proposed project are typically described in terms of the *expected* improvements, without specifying the ranges or distributions of the improvements. To the extent that the subjects have less information about these improvements than the policy maker or researcher, failure to accurately describe the uncertainties in surveys may not prevent the subjects from perceiving improvements that are more uncertain than the true distributions. Because higher uncertainties lead to higher commitment costs, more accurate description of the distributions will help reduce the commitment costs.

Although an empirical question, this type of policy-irrelevant commitment cost may be particularly high in a WTA question for unique environmental goods or personal health, situations in which WTA has been found to diverge significantly from WTP (Horowitz and McConnell forth-coming). For significant commitment costs to arise, the respondent must feel that it will be difficult to reverse the transaction if it is undertaken. Once a subject's health has been compromised (increased exposure to a carcinogen or unhealthy food), respondents may feel it will be very difficult to reverse the transaction (reverse the effects of exposure to a carcinogen). Thus, there may be high commitment costs due to the high cost of reversal. In contrast, once having purchased better health, respondents may feel it is easy to reverse the transaction (by engaging in unhealthy practices in the future), reducing the commitment cost in WTP.

These considerations require the researcher to design surveys that accurately reflect information about the good to be valued, as well as the ability to delay. In a CVM study to evaluate residents' WTP for cleaning up a local lake, Corrigan et al. (2002) found that when the respondents are explicitly told they will receive a second chance in the future to vote on the cleanup, WTP drops significantly, and the associated CC_P accounts for 25% to 57% of the intrinsic value. This result suggests that respondents' beliefs about delay possibilities can lead to significantly different WTP values, the difference being a commitment cost.

Real Markets and Policy Relevant Commitment Costs

A related issue is whether commitment costs exist in real market transactions. Unlike experiments and surveys, a key feature of a market transaction is that a consumer is not *forced* to make a decision in any time period. Rather, one can gather information up to the point where the benefit of further waiting does not compensate for the cost anymore. This can happen if one has already gathered enough information or if the cost of waiting is too high. For example, a shopper can obtain price information from all local stores by visiting them or by checking their advertisements, and then decide on the best deal. For goods that are part of daily consumption, she may already have enough information about these goods. In both cases, her level of uncertainty is low at the transaction time, and the commitment costs are likely to be small if they exist at all. In other circumstances, a consumer may be highly impatient if she happens to need the good urgently, again reducing the commitment costs. In the extreme, commitment costs completely vanish if she is sufficiently impatient (with $\beta = 0$)—the case for desperate last-minute shoppers, hungry tourists, or a variety of other common situations.

Of course, there are also situations where market transactions may not remove commitment costs. If a consumer is *induced* (i.e., given incentives) to make a transaction (by, for example, limited-time price discounts), the transaction price may contain commitment costs. As we discussed in section II, the price discounts are similar to QOVs and imply the existence of commitment costs that drive the difference between WTP and CV/EV.

In summary, if there is always the opportunity to gather at least a little more information, and if the cost of doing so is not too high, a consumer may never *completely* exhaust his or her learning opportunities before making a trade. Thus, the difference between *WTP*/*WTA* and *EV*/*CV* may be persistent in market transactions. But the difference will decline as the consumer becomes more efficient in information gathering and as the cost of waiting eventually becomes sufficiently high. The magnitude of persistent commitment costs requires empirical study.

Even in CVM surveys, it is important to distinguish between commitment costs that arise as a real part of the problem being studied and those that are induced via the format of the survey. The former will be policy-relevant commitment costs, where the value of interest is WTP or WTA inclusive of the relevant commitment costs. Some decisions are inherently characterized by uncertainty and irreversibility and therefore contain commitment costs that are not survey-induced, but rather are characteristics 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 commitment costs in making her decision. Additionally, a decision to build an elementary school or local hospital this year will likely have policy-relevant commitment costs.[16] In these cases, a survey that accurately replicates the real market features will elicit WTA and WTP measures that contain the commitment costs. But these commitment costs represent real uncertainty and should enter the welfare calculations, thus WTA or WTP are in fact appropriate welfare measures. Public good examples with uncertainty, irreversibility and future learning abound and, in fact, prompted the Arrow and Fisher (1974) inquiry into real options.

Furthermore, if the survey is intended to gauge the subjects' responses to a *decision* that the society faces, rather than to infer their *valuation*, commitment costs should again be part of the decision and is policy-relevant. Such a survey is similar to a referendum or a vote, reflecting the result of a collective decision. For example, polls are regularly conducted to measure the public's opinions on certain issues.

If the WTP/WTA divergence in surveys is due to policy-relevant option values, the

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

NOAA panel's recommendation to use WTP will be inapt when property rights would suggest that WTA is the more appropriate measure. However, if the divergence arises due to policy-irrelevant commitment costs that affect WTA more significantly than WTP (as it was argued may well be the case for health and unique environmental goods), then the NOAA panel recommendation is well founded.

Marketing Strategies

A central message of our model is that the WTP and WTA values are time-dependent, or more accurately, information-dependent. Because commitment cost CC_P reduces WTP from a consumer's valuation of a product, firms should have incentive to develop strategies that reduce or remove this commitment cost. We will show that many commonly used marketing strategies do have the potential of reducing the commitment costs or at least reacting to their existence.

A major conclusion of the introductory pricing literature (Shapiro 1983; Vettas 1997) is that prices of new products are typically low at initial introduction and gradually increase afterward. Shapiro (1983) argued that this price path may be caused by repeat purchases because early buyers, after using the product and thus knowing its (high) quality, will come back and buy the product again, raising the demand. Vettas (1997) showed that in the case of durable goods, if the consumers can communicate with each other and if high demand signals high product quality, a monopolist will have an incentive to reduce the price early to increase the quantity sold.

Even without repeat purchases or consumer communication, our model would predict an increasing price path for durable and other goods as long as consumers can gather information about the product as time goes by (such as consulting publications, like *Consumer Reports*). Given the limited information consumers may have about the new product, an initially lower price is a sensible response to the lower WTP (or a lower demand curve). Furthermore, the "limited time offer" of introductory prices reduces the ability of the consumers to delay (and still face the same low price) and raises the consumer's WTP. Of course, if early users of the product can spread information about the product to others, firms will have even higher incentive to subsidize early users (by reducing their prices further) to raise the WTP of potential buyers. In fact, firms may provide information about the new product themselves: New product promotion quite often is accompanied by heavy advertising and sometimes by demonstrations in stores (Heiman et al. 2001).

The advertising literature argues that informative advertising can increase demand by providing consumers with more information about the product, such as its features, price, and location of stores (Nelson 1970; 1974). Presumably if the consumers are risk-averse, more information about the product quality will increase their demand. Further, more information reduces a consumer's search cost for a preferred product, thereby increasing the demand. Our hypothesis provides an additional explanation: More information reduces the commitment cost and raises a consumer's WTP and consequently the overall demand for the product.

Firms regularly adopt measures that reduce irreversibility in consumers' purchasing decisions, effectively reducing or even eliminating the commitment cost in WTP. Examples include money-back guarantees for consumption goods, trial periods (say, 30 days) for services, and so on. These offerings also provide incentives for consumers to learn about the product before finally committing to purchase it. Using option value arguments, Heiman et al. (forthcoming) showed that money-back guarantees significantly increase the demand for the underlying product.

V. FINAL REMARKS

Hicksian welfare theory is static in nature, but decisions in reality are often dynamic. In this article, 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 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 commitment cost of forgoing the opportunity of better information. Thus, the Hicksian equivalence between WTP/WTA and CV/EV breaks down.

We also discussed the implications of our finding for a range of issues in welfare analysis, including the WTP/WTA disparity in experiments and surveys, survey design, welfare measurement using market data, and firms' marketing strategies. Future work is needed to carefully study each of these implications by developing models tailored to each situation. In particular, empirical research, experiments, and surveys are needed to test the importance of commitment costs in these cases.

Our dynamic decision model is similar to that found in the QOV literature. But our study is not about QOV per se. We study an application of a variation of QOV models to consumer decision making, in particular its implications for welfare analysis. Although investment theory has recognized the value of being flexible in dynamic investment decisions under uncertainty and irreversibility, the theory of consumer behavior and welfare measurement has only begun to incorporate the joint effects of uncertainty and irreversibility and the value of being flexible. Although there exist individual studies on various aspects of dynamic consumer behavior, there has not been a systematic theoretical framework that unites these aspects (as the QOV literature has done in dynamic investment analysis). Our article constitutes a first step toward such a framework. In the process, we found that even such a step yields significant implications for the fundamental welfare constructs of Hicksian welfare theory.

APPENDIX: 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 $p > 0$. 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 that predict that the good's value will be below price p with a probability higher than δ.

Assumption 1. For any $p \in (0, G_H]$, there exists $0 \le \delta < 1$ such that 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 that would predict that the good's value will be below the price with probability higher than a certain δ. The agent should not buy the good if these signals are realized. Because 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 $p \in (0, G_H]$.*

Proof. Choose any $p^* \in (0, G_H]$ and set the corresponding

$$\delta^* = 1 + \left[\int_0^{p^*} \max\{-c_P, G - p^*\} dF_{G|S}(G)\right] \Big/ (G_H - p^*) < 1.$$

We only need to show that $V(p^*, s) < 0$ for $s \in S(p^*, \delta^*)$. This is true because

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

The first inequality follows because

$$\begin{aligned} &\int_{p^*}^{G_H} \max\{-c_P, G-p^*\} dF_{G|s}(G) \\ &= \int_{p^*}^{G_H} (G - p^*) dF_{G|s}(G) \\ &= (G_H - p^*) F_{G|s}(G_H) - \int_{p^*}^{G_H} F_{G|s}(G) dG \\ &< (G_H - p^*) F_{G|s}(G_H) - (G_H - p^*) F_{G|s}(p^*) \\ &= (G_H - p^*)\text{Prob}_{G|S}(G \in [p^*, G_H]|s), \end{aligned}$$

where the second equality is from integration by parts and the inequality follows because $F_{G|s}(G)$ is strictly increasing in G. The second inequality in (A-1) follows from the fact that for $s \in S(p^*, \delta^*)$, $\text{Prob}_{G|s}(G \in [p^*, G_H]|s) < 1 - \delta^*$. The third inequality in (13) follows from the definition of δ^*. ■

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 $d(0) < 0$ because $u_2(0) = u_1(0) > 0$, and $d(G_H) > 0$ because $u_2(G_H) = 0$ 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. Because 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 strict 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 $p_2 > p_1$. Because $V(p, s)$ is strictly decreasing in p, we know $V(p_2, s) < V(p_1, s)$ and $S_{P2}(p_2) \supset S_{P2}(p_1)$. Because $V(p, s) < 0$ for $s \in S_{P2}(p)$, we get $u_2(p_2) - u_1(p_2) > u_2(p_1) - u_1(p_1)$, or $u_2(p_2) - u_1(p_2) = (1 - \beta)u_2(p_2) + d(p_2) > u_2(p_1) - u_1(p_1) = (1 - \beta)u_2(p_1) + d(p_1)$. Because $u_2(p)$ is strictly decreasing in p, we know $u_2(p_2) < u_2(p_1)$. Thus, $d(p_2) > d(p_1)$: $d(p)$ is strictly increasing in p and p_P is unique.

Proof of Proposition 1. Because $d(\cdot)$ 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 β. Because WTP_S is independent of β, $CC_P = WTP_S - WTP$ is increasing in β.

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

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

Equations (6) and (7) then directly follow.

Derivation of WTA

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

$$\text{(A-2)} \quad W(p, s) = \int_0^{G_H} (\max\{G - c_A, p\} - G)dF_{G|s}(G) = \int_0^{G_H} \max\{-c_A, p - G\}dF_{G|s}(G).$$

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

$$\text{(A-3)} \quad \pi_1(p) = W(p, 0) = \int_S W(p, s)dH(s)$$

$$\text{(A-4)} \quad \pi_2(p) = \int_S \max\{0, W(p, s)\}dH(s) = \int_{S_{A2}(p)} W(p, s)dH(s),$$

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 $S_{A1}(p) = S/S_{A2}(p) = \{s \in S : W(p, s) < 0\}$. $\pi_1(p) < \pi_2(p)$ 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

$$\text{(A-5)} \quad WTA_S = \bar{G}$$

$$\text{(A-6)} \quad CC_A = [\text{Prob}(S_{A1})/([1/\beta] - \text{Prob}[S_{A2}])] \times [E(G|S_{A1}) - \bar{G}],$$

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

REFERENCES

Arrow, Kenneth J., and Anthony C. Fisher. "Environmental Preservation, Uncertainty, and Irreversibility." *Quarterly Journal of Economics*, 88, 1974, 312–19.

Arrow, Kenneth, Robert Solow, Paul R. Portney, E. E. Leamer, R. Radner, and E. H. Schuman. "Report of the NOAA Panel on Contingent Valuation." *Federal Register*, 58, 1993, 4601–14.

Banerjee, Abhijit V. "A Simple Model of Herd Behavior." *Quarterly Journal of Economics*, 107(3), 1992, 797–817.

Bikhchandani, Sushil, David Hirshleifer, and Ivo Welch. "A Theory of Fads, Fashion, Custom, and Cultural Change as Information Cascades." *Journal of Political Economy*, 100(5), 1992, 992–1026.

Blackwell, D. "The Comparison of Experiments," in *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*. Berkeley: University of California Press, 1951, 93–102.

———. "Equivalent Comparisons of Experiments." *Annals of Mathematical Statistics*, 24, 1953, 265–72.

Bockstael, Nancy E., and Kenneth E. McConnell. "Welfare Measurement in the Household Production Framework." *American Economic Review*, 73, 1983, 806–14.

Carson, Richard. "Contingent Valuation: Theoretical Advances and Empirical Tests since the NOAA Panel." *American Journal of Agricultural Economics*, 79, 1997, 1501–07.

Corrigan, Jay R., Catherine L. Kling, and Jinhua Zhao. "The Dynamic Formation of Willingness to Pay: An Empirical Specification and Test." Working Paper, Iowa State University, 2002.

Cummings, Ronald G., and Laura O. Taylor. "Unbiased Value Estimates for Environmental Goods: A Cheap Talk Design for the Contingent Valuation Method." *American Economic Review*, 89, 1999, 649–65.

Dixit, Avinash K. "Investment and Hysteresis." *Journal of Economic Perspectives*, 6, 1992, 107–32.

Dixit, Avinash K., and Robert S. Pindyck. *Investment under Uncertainty*. Princeton, NJ: Princeton University Press, 1994.

Epstein, Larry G. "Decision Making and the Temporal Resolution of Uncertainty." *International Economic Review*, 21, 1980, 269–83.

Fisher, Anthony C. "Investment under Uncertainty and Option Value in Environmental Economics." *Resource and Energy Economics*, 22, 2000, 197–204.

Hammack, Judd, and Gardner Brown. *Waterfowl and Wetlands: Towards Bioeconomic Analysis*. Baltimore, MD: Johns Hopkins University Press, 1974.

Hanemann, W. Michael. "Information and the Concept of Option Value." *Journal of Environmental Economics and Management*, 16, 1989, 23–37.

———. "Willingness to Pay and Willingness to Accept: How Much Can They Differ?" *American Economic Review*, 81, 1991, 635–47.

Harbaugh, William, Kate Krause, and Lise Vesterlund. "Are Adults Better Behaved than Children? Age, Experience, and the Endowment Effect." *Economics Letters*, 70, 2001, 175–81.

Heiman, Amir, Bruce McWilliams, and David Zilberman. "Demonstrations and Money-Back Guarantees: Market Mechanisms to Reduce Uncertainty." *Journal of Business Research*, 54, 2001, 71–84.

Heiman, Amir, Bruce McWilliams, Jinhua Zhao, and David Zilberman. "Valuation and Management of Money-Back Guarantee Options." *Journal of Retailing*, forthcoming.

Henry, Claude. "Investment Decisions under Uncertainty: The Irreversibility Effect." *American Economic Review*, 64, 1974, 1006–12.

Hoehn, John P., and Alan Randall. "A Satisfactory Benefit Cost Indicator from Contingent Valuation." *Journal of Environmental Economics and Management*, 14, 1987, 226–47.

Horowitz, John K., and K. E. McConnell. "A Review of WTA/WTP Studies." *Journal of Environmental Economics and Management*, 44, 2002, 426–47.

———. "Willingness to Accept, Willingness to Pay and the Income Effect." *Journal of Economic Behavior and Organization*, forthcoming.

Horowitz, John K., K. E. McConnell, and John Quiggin. "A Test of Competing Explanations of Compensation Demanded." *Economic Inquiry*, 37, 1999, 637–46.

Hubbard, Glenn R. "Investment under Uncertainty: Keeping One's Options Open." *Journal of Economic Literature*, 32, 1994, 1816–31.

Kahneman, Daniel, and Amos Tversky. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica*, 47 (2), 1979, 263–91.

Kihlstrom, Richard E. "A 'Bayesian' Exposition of Blackwell's Theorem on the Comparison of Experiments," in *Bayesian Models in Economic Theory*, edited by Marcel Boyer and Richard Kihlstrom. North-Holland, 1984, 13–31.

Kolstad, Charles D. "Fundamental Irreversibilities in Stock Externalities." *Journal of Public Economics*, 60, 1996, 221–33.

Kolstad, Charles D., and Rolando M. Guzman. "Information and the Divergence between Willingness-to-Accept and Wilingness-to-Pay." *Journal of Environmental Economics and Management*, 38, 1999, 66–80.

List, John A. "Do Explicit Warnings Eliminate the Hypothetical Bias in Elicitation Procedures? Evidence from Field Auctions for Sportscards." *American Economic Review*, 91, 2001, 1498–507.

———. "Does Market Experience Eliminate Market Anomalies?" *Quarterly Journal of Economics*, forthcoming.

Mitchell, Robert, and Richard Carson. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Washington D.C.: Resources for the Future, 1989.

Neill, Helen R., Ronald G. Cummings, Philip T. Ganderton, Glenn W. Harrison, and Thomas McGuckin. "Hypothetical Surveys and Real Economic Commitments." *Land Economics*, 70, 1994, 145–54.

Nelson, P. "Information and Consumer Behavior." *Journal of Political Economy*, 78, 1970, 311–29.

———. "Advertising as Information." *Journal of Political Economy*, 82, 1974, 729–54.

Randall, Alan, and John R. Stoll. "Consumer's Surplus in Commodity Space." *American Economic Review*, 70, 1980, 449–55.

Ready, Richard C. "Environmental Valuation under Uncertainty," in *The Handbook of Environmental Economics*, edited by Daniel W. Bromley. Blackwell, 1995, 569–93.

Shapiro, Carl. "Optimal Pricing of Experience Goods." *Bell Journal of Economics*, 14, 1983, 497–507.

Smith, V. Kerry. "JEEM and Non-market Valuation: 1974–1998." *Journal of Environmental Economics and Management*, 2000, 39, 351–74.

Tversky, A., and D. Kahneman, "Loss Aversion in Riskless Choice: A Reference-Dependent Model." *Quarterly Journal of Economics*, 106, 1991, 1039–61.

Vettas, Nikolaos. "On the Informational Role of Quantities: Durable Goods and Consumers' Word-of-Mouth Communication." *International Economic Review*, 38, 1997, 915–44.

Zhao, Jinhua, and Catherine L. Kling. "A New Explanation for the WTP/WTA Disparity." *Economics Letters*, 73, 2001, 293–300.

———. "Environmental Valuation under Dynamic Consumer Behavior." Working Paper, Iowa State University, 2002.