Willingness-to-Pay, Compensating Variation, and the Cost of Commitment

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Abstract

We present a dynamic model of an agent's decision to purchase or sell a good under conditions of uncertainty, irreversibility, and learning over time. Her WTP contains both the intrinsic value of the good and a commitment cost 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 finding has important practical implications as it implies that observed WTP values are not always appropriate for welfare analysis.

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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), and 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 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 consumer's maximum willingness to pay 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. Likewise, experimental economists elicit WTP or WTA based on actual transactions to test a variety of consumer theory hypotheses including the validity of neoclassical indifference curves (Knetsch (1989)), the empirical disparity between WTP and WTA (Horowitz and McConnell (2000a)), and the equivalence between revealed and stated preference values (Cummings and Taylor (1999)).

In this paper, we explore the Hicksian concepts of compensating and equivalent variation as well as willingness-to-pay (and accept) in explicitly dynamic situations; specifically, where the agent is uncertain about the value of the good under consideration but can latter 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, WTP and WTA will depend critically on a variety of factors related to the timing of the formation of those 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 will not depend 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 upon 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,

[1] In fact, the literature on herd behavior focuses explicitly on information and the timing of decisions by a group of agents (Banerjee (1992) and Bikhchandani, Hirshleifer and Welch (1992)).

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. This information helps the agent to reduce the likelihood of having to reverse her 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 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 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 paper, 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 her learning opportunities and thus demands appropriate "compensation." Consequently, her WTP for a commodity will be reduced by a commitment cost, and her 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. We will show how the commitment costs are related to the QOV. Since 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

[2]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.

hold.

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 commitment costs and variables that affect the magnitude of these commitment costs are examined. In Section 2, we investigate the relationship between WTP/WTA and CV/EV. In Section 3, we discuss some of the implications of these theoretical results for applied 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. 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

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

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

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 $[0, G_H]$.[4] She knows that more information about G will be available in period two,

[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 to be zero. We could use a more general

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 Bayes 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 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.[5] 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

representation, such as G_L $(< G_H)$, without affecting the results of our model.

[5] 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.

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* 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 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 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 $WTA = p_A$.

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).[6] 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 $p \leq c_P$, $\max\{-c_P, G - p\} = G - p$ 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. 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.[7] 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

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

[7] 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).

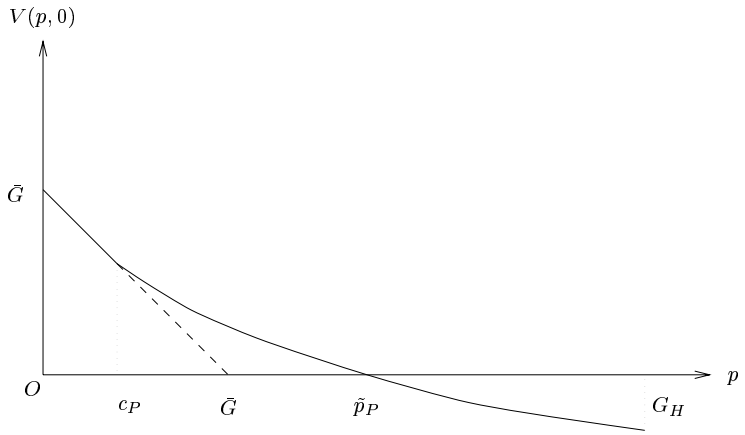


Figure 1: Static Welfare Measurement: WTP

consider this special case in greater detail later in this section.

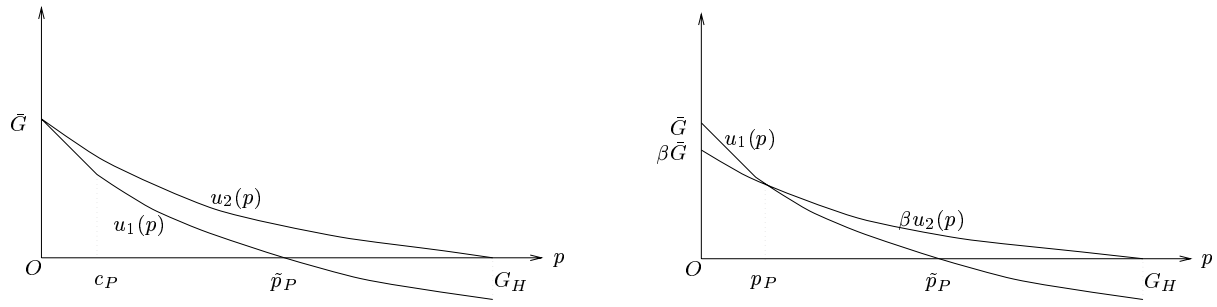
Let $u_1(p)$ be the agent's expected net surplus if she buys the good at price p in period one (without any signal). Then

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

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 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



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

Figure 2: Dynamic Welfare Measurement: WTP

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 is optimal (Hanemann, 1989). Then the WTP is the maximum price at which QOV is zero:[8] 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 "commitment cost" that measures the difference between the static and dynamic WTP: $CC_P = \tilde{p}_P - p_P \geq 0$, or written differently,

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

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, 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 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, while CC_P is expressed in terms of a price cut for both periods.

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

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

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 CC_P is measured in (permanent) price discounts.

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 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 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 $WTP_S = \bar{G}$. Appendix A shows that

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

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

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 $s \in S_{P2}$

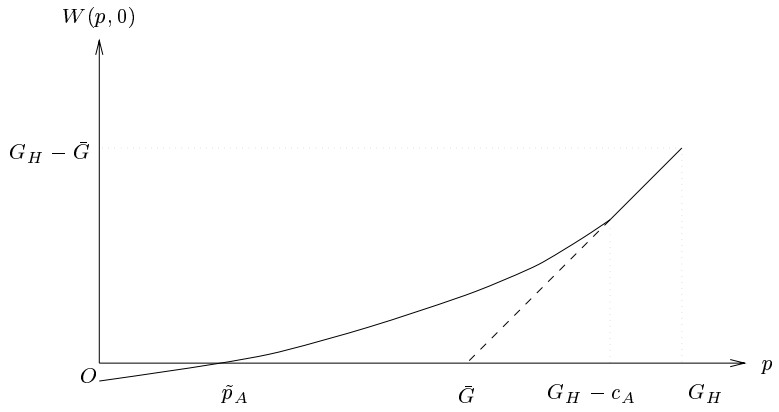


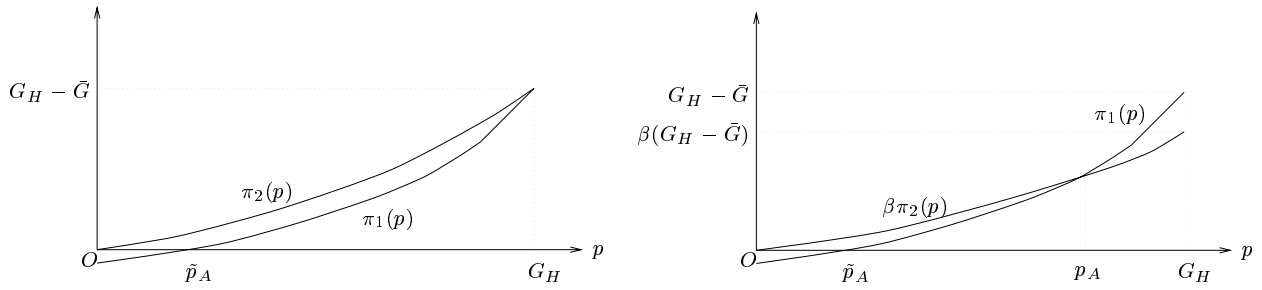
Figure 3: Static Welfare Measurement: WTA

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 $CC_P > 0$. 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, $\bar{G} - E(G|S_{P2})$.

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 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, $WTA = p_A > \tilde{p}_A = WTA_S$.



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

Figure 4: Dynamic Welfare Measurement: WTA

Defining the commitment cost of selling now as $CC_A = p_A - \tilde{p}_A \geq 0$, we know

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

Similar to Proposition 1, we have

Proposition 2 *WTA is increasing in β, the informativeness of signal S, and the re-purchase cost c_A. CC_A is increasing in β and the informativeness of S.*

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

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

2 WTP/WTA and the Hicksian Measures

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

$$U(m - \tilde{CV}, 1) = U(m, 0) \qquad U(m + \tilde{EV}, 0) = U(m, 1), \tag{10}$$

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 commitment costs. Since only WTP and WTA are observable in empirical welfare measurement (not WTP_S or WTA_S), 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. Further, a demand function based on WTP/WTA may not be homogeneous of degree zero in prices anymore: as prices double, the commitment costs of different goods may change disproportionately, affecting demand for each good differently. Finally, the area under an observed (or estimated) demand function will contain commitment costs and will not equal CV/EV, complicating welfare assessments. It is therefore important in applied welfare analysis to find out whether commitment costs exist, and, if so, their magnitude.

[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.

3 Implications

Based on our model, commitment costs 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 β 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. 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 will discuss situations where 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.

3.1 WTP/WTA Divergence in Experiments, Surveys and Real Markets

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.[10] These findings have seriously challenged Hicksian welfare theory: Using a meta-analysis of over 200 WTA

[10] See Horowitz and McConnell (2000a) for a nice review of the literature on these divergences and Hammack and Brown (1974) for one of the first contingent valuation illustrations.

and WTP observations from 45 experiments and surveys, Horowitz and McConnell (2000b) 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, Solow, Portney, Leamer, Radner and Schuman (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) and Tversky and Kahneman (1991)). This approach is inconsistent with Hicksian theory and posits that the structure of the utility function depends upon 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, Krause and Vesterlund (1998) and Horowitz and McConnell (2000a)).

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.[11]

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

Our results provide another possible and 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:

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

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.[12]

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 (1999)), we argue that experiments and surveys require a subject to make her decision (buying/selling in experiments and a particular answer in surveys) within a certain time frame (within the experiment or survey session), forgoing her future learning opportunities. Her decision is typically irreversible, and the subject is willing to postpone her decision. Together, these conditions can lead to commitment costs in these settings. In fact, we showed that the commitment costs can generate divergences equal to the total intrinsic value of the good. We also identified published experiment results that are consistent with our hypothesis.

The essence of our explanation is that the WTP/WTA divergence in experiments and surveys 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

[12] 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.

theory. The inconsistency between the evidence and the Hicksian theory may have arisen because the theory is static and the agent decisions are dynamic in nature. Therefore, the (static) Hicksian theory needs to be augmented with dynamic and uncertainty considerations. A critical next step is to conduct experiments and surveys that can test our hypothesis against other explanations that are based on the divergence between CV and EV.

A related issue is whether commitment costs exist in real market transactions. Different from experiments and surveys, a key feature of market transaction is that a consumer is not *forced* to make a decision in any time period. Rather, she can gather information up to the point where the benefit of further waiting does not compensate the cost anymore. This can happen if she 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 upon 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 1, the price discounts are similar to quasi-option values, 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 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 option values requires empirical study.

3.2 Commitment Costs in Stated Preference Surveys

The possible existence of commitment costs in stated preference surveys raises the question of the validity of routinely using WTP/WTA as measures of CV/EV in nonmarket valuation settings. In this regard, 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 that should be included in a benefits assessment whereas the latter are policy-irrelevant and researchers should design studies to minimize their presence.

For example, policy-irrelevant commitment costs may be induced (probably inadvertently) by the researcher who forces a time limit on a subject or inaccurately overstates uncertainty in a stated preference. 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 (2000b)). In order 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.

However, there are cases 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.[13] 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.

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

3.3 Marketing Strategies

A central message of our model is that the WTP and WTA values are time dependent, or more accurately, information dependent. Since the commitment cost CC_P reduces WTP from a consumer's valuation of a product, firms should have incentive to develop strategies that reduce or

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

remove this commitment cost. We show below 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) and Vettas (1997)) is that prices of new products are typically low at initial introduction and gradually increase afterwards. Shapiro (1983) argued that this price path may be caused by repeat purchases since 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 paths 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 Report*). 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). Further, 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 as Vettas (1997) argued, 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, McWilliams and Zilberman (forthcoming)).

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) and Nelson (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 her 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. Our model also suggests that price advertising (say in Sunday newspapers) by some stores may actually help the sales of competing stores, if the advertising is unbiased in the sense that it lists all prices.

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, etc. 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. (1998) showed that money-back guarantees increase the demand for the underlying product.

4 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 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 is necessary to test the importance of commitment costs in these cases.

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 $p > 0$. 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 δ.

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 $p \in (0, G_H]$.*

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

$$\begin{aligned} V(p^*, s) &= \int_0^{p^*} \max\{-c_P, G-p^*\} dF_{G|s}(G) + \int_{p^*}^{G_H} \max\{-c_P, G-p^*\} dF_{G|s}(G) \\ &\leq \int_0^{p^*} \max\{-c_P, G-p^*\} dF_{G|S}(G) + (G_H - p^*) \text{Prob}_{G|S}(G \in [p^*, G_H]|s) \\ &< \int_0^{p^*} \max\{-c_P, G-p^*\} dF_{G|S}(G) + (G_H - p^*)(1-\delta^*) < 0. \quad (13) \end{aligned}$$

The weak inequality follows from the fact that for $s \in S(p^*, \delta^*)$, $\text{Prob}_{G|s}(G \in [p^*, G_H]|s) > \delta^*$. The strict inequality 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 $d(0) < 0$ 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 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 $p_2 > p_1$. 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 strictly 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 β. Since 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 and 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, 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

$$\begin{aligned} W(p,s) &= \int_0^{G_H} (\max\{G - c_A, p\} - G)\, dF_{G|s}(G) \\ &= \int_0^{G_H} \max\{-c_A, p - G\} dF_{G|s}(G). \end{aligned} \tag{14}$$

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

$$\pi_1(p) = W(p, 0) = \int_S W(p, s) dH(s) \tag{15}$$

$$\pi_2(p) = \int_S \max\{0, W(p, s)\} dH(s) = \int_{S_{A2}(p)} W(p, s) dH(s), \tag{16}$$

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

$$WTA_S = \bar{G} \tag{17}$$

$$CC_A = \frac{\text{Prob}(S_{A1})}{\frac{1}{\beta} - \text{Prob}(S_{A2})} \left[E(G|S_{A1}) - \bar{G} \right], \tag{18}$$

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, $CC_A > 0$.

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