Loss of Substitutability: A Note of Disparity between WTP and WTA

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Abstract: This note examines the disparity between willingness-to-pay (WTP) and willingness-to-accept (WTA) in the nonmarket valuation of environmental public goods. We observe that the commonly cited substitution effect and endowment effect, while often used to explain this disparity, address distinct conceptual questions. Building on this, we propose an integrated model that incorporates both effects within a reference-dependent framework. Our findings demonstrate that compensation demanded for lost substitutability is unbounded under a neoclassical framework but constrained within a loss-aversion context. These results offer a foundation for empirical testing to advance understanding of this persistent issue.

Keywords: Environmental economics, Willingness-to-pay, Willingness-to-accept, Loss aversion, Substitutability, Environmental public goods.

INTRODUCTION

Experimental evidence shows a substantial and persistent disparity between willingness-to-pay (WTP) and willingness-to-accept (WTA) for goods and services, particularly in the valuation of environmental public goods. WTP refers to the maximum amount an individual is willing to pay to finance an environmental public good, while WTA represents the minimum amount they would accept to forgo or sell it (Dragicevic and Shogren, 2017; Dragicevic, 2019; Dragicevic and Shogren, 2021). Laboratory studies further affirm the robustness of this disparity (Knetsch and Sinden, 1984; Brookshire and Coursey, 1987; Shogren *et al*., 1994).

Theoretical explanations for this persistent gap often invoke either the substitution effect (Hanemann, 1991) or the endowment effect (Kahneman and Tversky, 1979; Thaler, 1980). These effects operate through changes in quality or fixed quantities of both environmental public and private goods. The substitution effect arises from an agent's limited ability to trade one good for another, particularly when substitutes are imperfect. Consequently, the disparity between WTP and WTA widens as the availability of substitutes declines (Shogren *et al*., 1994). In contrast, the endowment effect suggests that individuals place a higher value on avoiding losses than on acquiring equivalent gains, reflecting a cognitive bias where losses loom larger than comparable gains.

Morrison (1997) attempts to reconcile these effects by proposing a model that integrates them. Similarly, Hanemann (1999) suggests that a quasi-concave utility function, inversely related to the substitution effect, can account for both the standard WTP-WTA gap and the disparities in valuation of gains versus losses.

This note addresses the ongoing debate regarding the substitutability between environmental public goods and private goods (or income). Here, we conceptualize the substitution effect as an opportunity loss and the endowment effect as a loss of substitutability. We propose that both effects are influenced by the degree of substitutability between the goods. This approach reveals a common misconception: substitutability and loss aversion each reflect distinct interpretations of WTA. By examining these effects within a unified reference-dependent framework, we find that the compensation required for reduced substitutability is unbounded within the neoclassical framework, yet constrained when accounting for loss aversion.

Section 1 introduces the concepts of opportunity loss and loss of substitutability. Section 2 presents an analysis of boundedness properties. Concluding remarks are provided in Section 3.

1. THE OPPORTUNITY LOSS AND THE LOSS OF SUBSTITUTABILITY

Given a preference $u(x,q)$ where q and the x's—bought by income y—respectively represent the environmental public and private goods (or income), WTP^{+} for q is defined as the maximum amount an agent is willing to pay to guarantee the increase of the environmental public goods' level from q^0 to q^1 $(q^0 < q^1)$. Likewise, WTA^{+} for q is the minimum amount an agent is willing to receive to forego the increase to q^1. The symmetric reasoning relates to WTP^{-} in order to avoid the environmental public goods' degradation; and to WTA^{-} to tolerate it.

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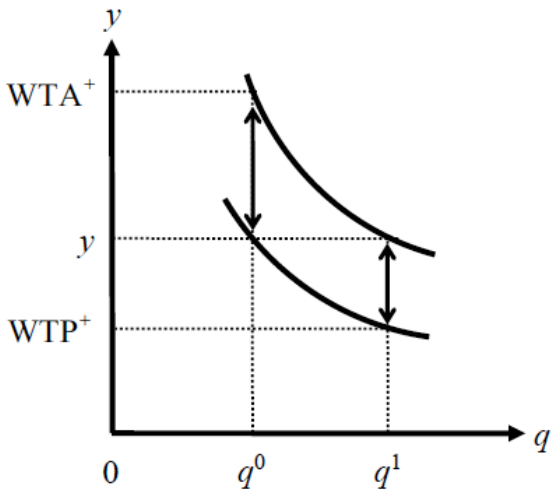

Figure 1: Substitutability between *q* and the *x*'s.

Combinations of the *x*'s (*via y*) and *q* along the indifference curves being imperfectly substitutable, agents display convex preferences and $WTP^{+} < WTA^{+}$ (Figure **1**).

In the usual neoclassical framework, preferences are independent of the initial endowments. That is why Hanemann (1991) points out that Kahneman and Tversky's (1979) loss aversion differs from the Hicksian preferences. To address this issue, Bateman *et al*. (1997) incorporate reference points into the neoclassical framework. Their work permits identifying the equivalent gain (WTA^{+}), which is the minimum amount an agent is willing to receive to sacrifice a foregone gain ($q^1 \equiv q^0 + \Delta$, where $\Delta \geq 0$ is the change from status quo level q^0) and the compensating loss (WTA^{-}), which is the minimum amount an agent is willing to receive to tolerate a net loss ($q^1 \equiv q^0 - \Delta$). Unlike the standard disparity where the changes go in the same direction ($+\Delta$ or $-\Delta$), the gain and loss disparity is the study of changes that depart in opposite directions ($+\Delta$ and $-\Delta$). An endowed agent introduces a reference point and shifts their position on the map, such that the shape of their indifference curve is altered. The income or wealth effect—the spacing between the indifference curves—does not count, for the gain and loss perspective involves a single curve observed from some positive or negative shift. Figure **2** illustrates the welfare indices observed from the reference point coordinates (q^0, y) of the utility arguments. The grey curve depicts some pre-endowed utility in *q* and the *x*'s (*via y*). The inclusion of context-dependence changes the initial utility to either a gain in utility $(+\Delta)$ or a loss in utility $(-\Delta)$.

In the behavioral framework of loss aversion, Tversky and Kahneman (1991) introduce a value function where agents have different preferences over gains and losses relative to their status quo. Figure **3** illustrates the welfare measures from the loss aversion perspective. The reference point coordinates (r_q, r_x) stand for the initial use of environmental public goods *q* and the initial consumption of private goods *x* (*via y*). Their model explains the source of the gain and loss disparity. Although the authors assert that the disparity between WTP and WTA is an implication of loss aversion, what they really compare is WTP^{+} with WTA^{-}. For that reason, their design cannot interpret the notion of foregone gain, nor can explain the suggested disparity between WTP^{+} and WTA^{+}.

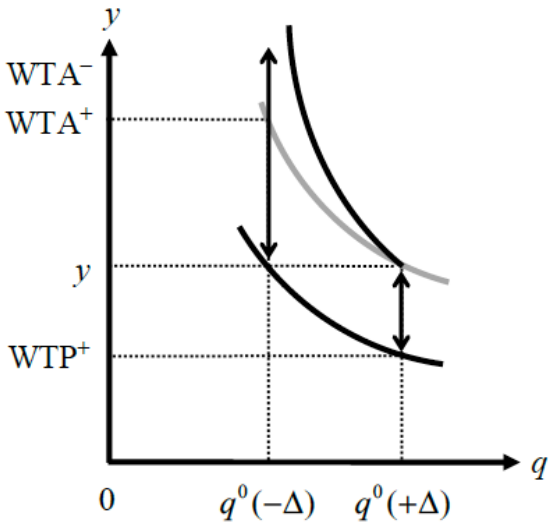

Figure 2: Reference-dependent preferences.

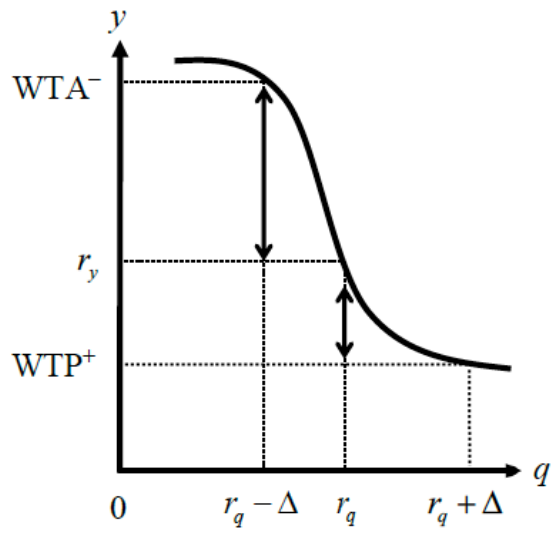

Figure 3: Welfare measures in loss aversion.

Consider the concept of opportunity loss (foregone gain) as the opportunity cost associated with enhancing the level of environmental public goods, analogous to the potential interest earnings in a bank account. Under the convexity assumption, the substitution effect in the neoclassical framework exclusively reflects this opportunity loss: as substitutability decreases, the opportunity loss increases accordingly. However, the agent's utility

remains unchanged, with the status quo representing the minimum outcome. This observation leads us to our first formal definition.

DEFINITION 1. Imperfect substitutability, characterized by a convex-shaped indifference curve, represents an opportunity loss between environmental public goods and private goods (or income).

When an agent assesses a true loss, weighing it against an equivalent gain, this perceived loss becomes a net loss. This net loss signifies a pivotal shift, as agents now account for goods that are no longer substitutable, explicitly valuing this reduction in substitutability by adjusting their preferences and adopting a steeper indifference curve. The lower the initial substitutability between environmental public goods and private goods (or income), the steeper the slope of both the original and adjusted indifference curves. In Tversky and Kahneman's framework, this aligns with the loss aversion portion of the value curve. To facilitate comparisons between models, reference-dependence must be introduced. This leads to our second formal definition.

DEFINITION 2. The preference shift induced by reference-dependence expresses a loss of substitutability between the goods.

2. THE LOSS OF SUBSTITUTABILITY AND BOUNDEDNESS

Randall and Stoll (1980) demonstrate that the standard disparity is constrained by the ratio between the price flexibility of income and endowment. Cook and Graham (1977) argue that the compensation demanded for irreplaceable commodities—assumed here to be imperfectly substitutable—depends on the initial wealth or endowment level. As the probability of loss nears certainty, WTA^{-} tends toward infinity. Amiran and Hagen (2003) propose that high wealth levels yield an infinite WTA^{+} for irreversible losses of environmental public goods (effectively WTA^{-}) when the utility function is asymptotically bounded. They show that the income elasticity of the inverse compensated demand is bounded above and below by positive values independent of the quantity of environmental public goods. Although the substitution effect is crucial as it introduces frictional trade-offs between environmental public and private goods (or income), their reference-independent model only accounts for opportunity losses, not net losses.

In the neoclassical framework with reference-dependent preferences, we claim that the loss of substitutability, which induces the shifting on the map, implicates unbounded compensation demanded ($WTA^{-} \to \infty$). In order to prove our claim, we replace the nonsatiation assumption by the following assumption on the preferences over reference points.

ASSUMPTION. For any income level y sufficient to acquire quantities of x, the status quo r_q is strictly preferred to the net loss of public goods $r_q - \Delta \geq q^0$, where $\Delta \geq 0$. Formally, the assumption verifies the following strict inequality

$$u(r_q - \Delta, y) \leq u(r_q, y). \tag{1}$$

Figure **4** shows that the argument of substitutability intervenes twice. Outcome (1) lies in the convexity of curvature of the initial grey indifference curve, for the slope increases with opportunity losses. Outcome (2) results from the loss of substitutability, yielding a shift to an updated utility curve asymptotic at q^0. The combination of two yields an unbounded level of compensation s unable to offset the loss of substitutability. Algebraically, we have

$$u(r_q - \Delta, y) \leq u(r_q, y) \leq u(r_q - \Delta, y + s). \tag{2}$$

PROPOSITION 1. In the neoclassical framework incorporating reference-dependence, the loss of substitutability between imperfectly substitutable environmental public goods and private goods (or income) results in unbounded compensation demands.

Proof in the Appendix

The limit of WTA^{-} is due to the pivoting of the convex indifference curve. Contrary to Cook and Graham (1977) and similarly to Amiran and Hagen (2003), our curve is asymptotic at critical levels of losses around q^0.

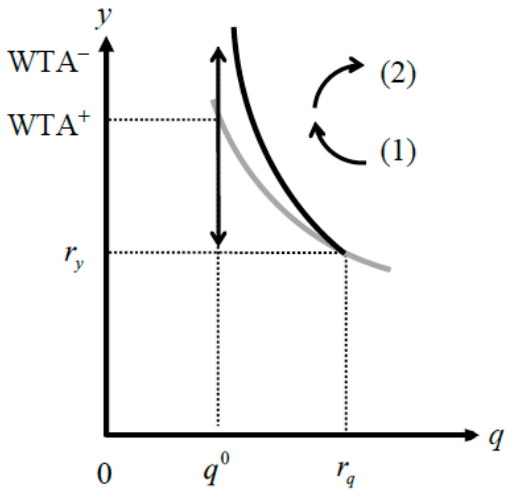

Figure 4: Unbounded compensation demanded.

In contrast to prior models that attribute infinite compensation in terms of numéraire to substitutability, our framework is independent of initial wealth levels,

initial endowments in market goods, or the boundedness of the utility function. Instead, it relies solely on the opportunity loss associated with imperfect substitutability and the loss of substitution opportunities between the goods.

The context-dependence inherent in loss aversion yields a distinct outcome. The agent substitutes the loss of environmental public goods with monetary compensation when positioned above the kink point, while below this point, the reverse occurs. At the kink point, with coordinates (r_q, r_y), the agent is equidistant from both reference points and exhibits perfect indifference between environmental public goods and private goods (or income). Any other point along the nonlinear curve indicates some degree of opportunity loss. The compensation demanded, reflecting the loss of substitutability, corresponds to the segment above the kink point. As shown in Figure **1**, the marginal valuation reveals diminishing sensitivity in the context of loss aversion. We have

$$v(r_q - \Delta) \le v(r_q) \le v(r_q) + v'(r_q)(-\Delta) \quad \text{as} \quad r_q - \Delta \le r_q \,. \tag{3}$$

As $r_q - \Delta$ moves further from the reference point r_q, additional reductions in *q* produce progressively smaller changes in the value function. In other words, diminishing sensitivity suggests a decreasing impact of the loss of substitutability. Unlike the increasing slope for greater losses observed in the neoclassical framework, the reduction in the value function from the downgrading of environmental public goods lessens as the agent shifts away from the reference point. This implies a bounded WTA^{-} value for the loss of substitutability.

PROPOSITION 2. Due to the consistent diminishing sensitivity associated with loss aversion, the compensation required for the loss of substitutability between imperfectly substitutable environmental public goods and private goods (or income) remains bounded.

Proof in the Appendix

The neoclassical framework and loss aversion differ in their formal representation of the loss of substitutability. When we overlay the segments illustrating WTA^{-}, their respective curvatures reveal distinct behaviors (Figure **5**). Agents within the neoclassical framework, depicted by the grey segment, display increasing marginal disutility as $(r_q - \Delta) \to q^0$. In contrast, agents governed by loss aversion, represented by the black segment, show high sensitivity to small losses but reduced sensitivity to larger losses due to diminishing marginal valuation. As changes extend further from a reference point, their incremental impact diminishes, resulting in limited frictions in trade-off loss. Consequently, loss-averse agents demand bounded compensation.

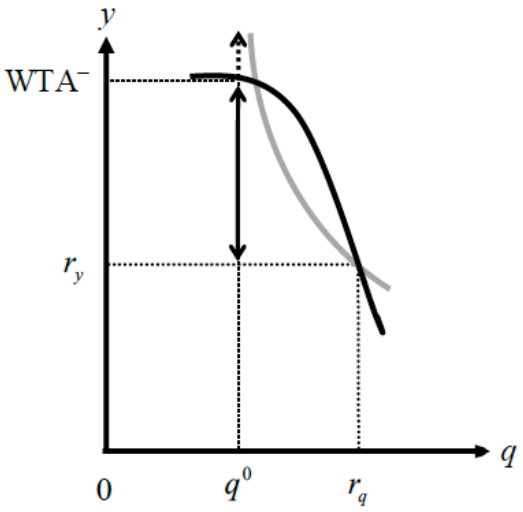

Figure 5: Loss of substitutability.

Our findings present novel implications. In cases of reduced substitutability between environmental public goods and private goods (or income)—commodities known to be imperfectly substitutable or subject to opportunity loss—endowed neoclassical agents demand unbounded compensation, while loss-averse agents require bounded compensation. This phenomenon resembles an anchoring effect or adherence to the status quo, as neither type of agent adjusts their reference points. While psychologists often view loss aversion as a challenge to rational preferences, our results indicate that beyond a certain threshold of change in environmental public goods, the perceptual sensitivity to the loss of substitutability limits agents' tendency to overvalue losses.

3. CONCLUSIONS

The concept of opportunity loss provides insight into the standard disparity observed in Hanemann's analysis. When a scenario involves a true loss rather than a foregone gain, opportunity loss becomes a loss of substitutability, amplifying the initial disparity, as agents assign high value to goods they can no longer substitute. Experimental evidence from Boyce *et al*. (1992) and Chapman (1998) supports this view. Similar to findings by Hanemann (1991) and Amiran and Hagen (2003), our results demonstrate that unbounded compensation demands arise from the inability to substitute environmental public goods with private goods (or income). However, these results clarify the nature of welfare measures without imposing functional constraints. Finally, we observe that loss aversion results in bounded compensation demands, a proposition that merits laboratory testing. Determining whether agents assign bounded or unbounded values to environmental public goods losses could address the longstanding question of which model best

captures preferences regarding environmental public goods.

Our findings indicate that loss aversion may play a role in limiting individuals' responses to severe environmental degradation, potentially contributing to the prevalent inaction seen in response to climate change and biodiversity decline (Dragicevic, 2018; Dragicevic, 2024). Specifically, if individuals exhibit diminishing sensitivity to progressively larger environmental losses—assigning greater value to smaller, immediate losses than to more substantial, abstract ones—they may show reduced motivation to endorse extensive compensatory measures or proactive environmental policies. This inherently bounded compensation demand, characteristic of loss-averse behavior, suggests that individuals might undervalue the cumulative, long-term effects of environmental degradation (Dragicevic, 2020). Consequently, this perceptual limitation may lead to a short-sighted approach toward critical environmental risks, reinforcing a preference for maintaining the status quo and postponing significant interventions needed to address or reverse ecological decline. Our results, therefore, highlight a psychological barrier that could be a key factor in the current restrained response to accelerating ecological crises (Dragicevic, 2024).

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CONFLICTS OF INTEREST

The author declares that there are no conflicts of interest associated with this work.

APPENDIX

Appendix A—Proof of Proposition 1

For $q^0 \le r_q - \Delta < r_q$ with $\Delta \ge 0$, consider an individual with a utility function $u(q, y)$, where $q \ge 0$ represents the quantity of an environmental public good while $y \ge 0$ represents the income or consumption of private goods. The utility function $u(q, y)$ is increasing in both *q* and *y*, that is, $\frac{\partial u}{\partial q} > 0$ and $\frac{\partial u}{\partial y} > 0$. The individual starts with the reference level r_q of the public good and income *y*, so their utility is $u(r_q, y)$. We assume $u(r_q, y) = u(q^0, y)$. The public good decreases by Δ, resulting in a new level $q = r_q - \Delta$. Since *u* is increasing in *q*, we have $u(r_q - \Delta) \le u(r_q, y)$. This means the individual's utility decreases due to the loss of the public good.

We seek the amount of monetary compensation *s* needed to restore the individual's utility to its original level $u(r_q, y)$ after the decrease in *q*. Let $z(q)$ be the income level required at public good level *q* to maintain the original utility $u(r_q, y) = u(r_q, z(q))$. Since *u* is increasing in *y*, $z(q)$ is uniquely defined for each *q*. As *q* decreases, $z(q)$ increases because more income is needed to compensate for the loss in *q*. At the initial level r_q, the required income to maintain utility $u(r_q, y)$ is $z(r_q) = y$. At the decreased level $r_q - \Delta$, the required income is $z(r_q - \Delta)$. Define compensation *s* as $s = z(r_q) - z(r_q - \Delta)$. Since $z(r_q) \ge z(r_q - \Delta)$, we have $s \ge 0$. The compensation *s* is the additional income needed to offset the utility loss from the decrease in the public good. With this compensation, the individual's utility is restored or $u(r_q - \Delta, y + s) \ge u(r_q, y)$. For any income *y*, we have $u(r_q - \Delta, y) \le u(r_q, y)$, because $r_q - \Delta \le r_q$ and *u* is increasing in *q*. Likewise, $u(r_q, y + s) \ge u(r_q, y)$ because $y + s \ge y$ and *u* is increasing in *y*. This implies $u(r_q - \Delta, y) \le u(r_q, y) \le u(r_q - \Delta, y + s)$. If the substitutability between *q* and *y* decreases, the marginal rate of substitution increases. As the substitutability approaches zero, we observe $\left|\frac{\partial u/\partial q}{\partial u/\partial y}\right| \to \infty$. The compensation *s* required to maintain utility in the face of a decrease in *q* becomes unbounded as the substitutability between *q* and *y* decreases. Therefore, in the neoclassical framework incorporating reference dependence, the loss of substitutability between imperfectly substitutable environmental public goods and private goods (or income) results in unbounded compensation demands.

Appendix B—Proof of Proposition 2

For all $(r_q - \Delta) \in (0, r_q]$ where $\Delta \ge 0$ and $\Delta \le r_q$, consider a value function *v* defined on $\mathbb{R}_+^*$ with $(0, r_q]$. Since we are working with positive monetary compensations, we represent the shape of losses in a positive space. Since

v is nonincreasing and concave, we have $v'(x) \le 0$. By the concavity of *v*, for any $x \in (0, r_q]$, the function lies below its tangent at r_q and $v(x) \le v(r_q) + v'(r_q)(x - r_q)$. When replacing *x* with $r_q - \Delta$, we observe that $v(r_q - \Delta) \le v(r_q) + v'(r_q)(r_q - \Delta - r_q) = v(r_q) + v'(r_q)(-\Delta)$. Since $v'(r_q) \le 0$ and $\Delta \ge 0$, we have $v'(r_q)(-\Delta) \ge 0$. Therefore $v(r_q - \Delta) \le v(r_q)$. The inequality becomes $v(r_q - \Delta) \le v(r_q) + \delta$, where $\delta = v'(r_q)(-\Delta) \ge 0$. However, since *v* is non-increasing, $v(r_q - \Delta) \le v(r_q)$. This implies $v(r_q - \Delta) \le v(r_q) \le v(r_q) + \delta$. The inequality confirms that $v(r_q - \Delta)$ is bounded below by $v(r_q)$. The maximum utility loss from decreasing *q* from r_q to $r_q - \Delta$ is $\Delta v = v(r_q) - v(r_q - \Delta)$. Since $v(r_q - \Delta) \ge v(r_q) + v'(-\Delta)$ due to concavity, the utility loss satisfies $\Delta v \le -v'(r_q)\Delta$. Because $v'(r_q) \le 0$, the right-hand side is a finite positive value. As Δ increases up to r_q, the total utility loss is bounded by $\Delta v_{\max} = v(r_q) - v(0) < \infty$. The compensation required to offset the utility loss from a decrease in the public good *q* is proportional to Δv. Since Δv is bounded, the required compensation is also bounded.

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